# Notice No. 5

## Rules and Regulations for the Classification of Offshore Units, July 2014

The status of this Rule set is amended as shown and is now to be read in conjunction with this and prior Notices. Any corrigenda included in the Notice are effective immediately.

## Issue date: June 2015

| Amendments to | Effective date |
|---|---|
| Part 3, Chapter 1, Section 2 | 1 July 2015 |
| Part 3, Chapter 2, Section 1 | 1 July 2015 |
| Part 3, Chapter 8, Section 5 | Corrigendum |
| Part 3, Chapter 10, Sections 1, 2, 3, 4 & 5 | 1 July 2015 |
| Part 3, Chapter 10, Section 6 | Corrigendum |
| Part 3, Chapter 10, Sections 7, 8, 9, 10, 11, 12, 15 & 16 | 1 July 2015 |
| Part 3, Chapter 14, Sections 1, 2, 3, 4, 5, 6, 7 & 8 | 1 July 2015 |

Lloyd's Register

# Part 3, Chapter 1

# General Requirements for Offshore Units

**Effective date 1 July 2015**

## ■ *Section 2* **Information required**

### 2.3 Demarcation between Process and Marine Systems

*2.3.1* A classification demarcation plan is to be submitted for approval that identifies any boundaries of classification.

*2.3.2* The unit will encompass a split between the traditional Classification scope and that nominally described as process plant. It is noted that particularly with respect to new build projects the differentiation can lack clarity and it is not purely a function of location of the systems on the unit. Accordingly, a list of items to be considered under Classification requirements is to be developed, this may be extracted from the project equipment list, associated P&ID's and shall be agreed with LR. The equipment list shall also be used to identify those systems which fall inside and outside of Class and will form the basis of a classification demarcation plan for the unit.

*2.3.3* It should be noted that the location of an item rather than its function can influence the decision for inclusion within the Classification list of items. By example a tank serving a topsides process, that would normally be considered part of the topsides process plant, should be considered a Class item if it is located within the hull and adversely impacts the overall risk.

*2.3.4* It should be noted that the forgoing has been written with facilities encompassing a significant process plant in mind. However, it is recognised that other facilities e.g. crane barges will also benefit from this approach. Accordingly, in these instances, an equipment list, associated P&ID's, if appropriate, and plot plan are to be submitted for review.

# Part 3, Chapter 2

# Drilling Units

**Effective date 1 July 2015**

## ■ *Section 1* **General**

### 1.2 Class notations

*1.2.5* When, at the request of an Owner, a unit is to be verified in accordance with the Regulations of a National Administration, a descriptive note will be included in the ~~ClassDirect Live~~ Class Direct website.

*All instances of* ClassDirect Live *have been amended to* Class Direct *throughout this Part.*

*All instances of* Class Direct Live *have been amended to* Class Direct *throughout this Part.*

*All instances of* CD Live *have been amended to* Class Direct *throughout this Part.*

# Part 3, Chapter 8

# Process Plant Facility

**Corrigendum**

## ■ *Section 5* **Mechanical equipment**

**5.4 Materials**

*5.4.4* For selection of acceptable materials suitable for hydrogen sulphide contaminated products (sour service), reference is to be made to the ISO 15156/NACE Standard in Appendix A, ~~A1.2.21~~ A1.2.22.

# Part 3, Chapter 10

# Positional Mooring Systems

**Effective date 1 July 2015**

## ■ *Section 1* **General**

**1.1 Application**

*1.1.1* This Chapter applies to offshore units with positional mooring systems. This has been abbreviated to PMS.

*1.1.4* The requirements of this Chapter are not applicable to the mooring tethers on tension-leg units. For the design requirements of tension-leg units, *see* Pt 4, Ch ~~5~~ 4.

*1.1.6* When other codes or standards are proposed, gap analysis and risk assessments are to be provided by the Owner/designers to demonstrate the alternative codes or standards provide an equivalent level of safety to the requirements of this section. Acceptance of the alternative codes or standards will be subject to the alternative standards being agreed by LR to give an equivalent level of safety to the Rule requirements.

**1.3 Definitions**

*1.3.2* **Offshore Unit**. ~~Floating structure permanently moored at a specific location.~~ *See* Pt 1, Ch 2, 2.1.13 and for the definitions of specific types relevant to this section such as **Mobile offshore unit** *see* Pt 1 Ch 2, 2.1.10 and **Floating offshore installation** *see* Pt 1, Ch 2, 2.1.9.

*1.3.8* **Single-point mooring**. An offshore positional mooring ~~facility based on a~~ system arrangement in which the offshore unit freely weathervanes about a geostationary structure, generally using an internal or external turret, single buoy or single tower, *see* Ch 2,1.2.6.

**1.4 Plans and data submission**

*1.4.1* The positional mooring system will be subject to review and approval. The following information and plans are to be submitted in ~~triplicate~~ an agreed electronic format, to cover the design review and class approval of the positional mooring system:
(a) Plans of the positional mooring system and associated equipment are to be submitted including the following, as applicable:

- General arrangement of offshore floating unit (including hull and topsides general arrangements).
- Layout and arrangement of deck mooring equipment and support structures.
- Structural arrangement of mooring equipment, support structure and attachment point to the main structure or hull of the Offshore Unit.
- Mooring layout.
- Field layout

- Anchor lines and fittings assembly.
- Anchor points.
- Fairleads/bending shoes, including associated mechanism, articulation or stopper.
- Cable (i.e. mooring line, steel wire or fibre rope or chain) stoppers or connectors.
- Winches, windlasses or tensioners.
- Deck equipment used in support of the mooring line failure response plan.

*1.4.2* ~~Single copies of t~~The following supporting plans, data, calculations or documents are to be submitted in an agreed electronic format:

(a) General:
- Mooring design premise or basis of design.
- Moored unit details (dimensions and main particulars).
- Corrosion protection strategy and/or corrosion rates.

(b) Specifications:
- Materials.
- Mooring line components, mooring ~~E~~equipment and fittings.
- Model testing.

(c) Data reports:
- Environmental criteria (covering extreme as well as ambient conditions and all applicable operating environmental limits) and in addition for floating offshore installations at a fixed location:
- Detailed specialist environmental reports.
- Sea bed conditions.
- Soil and soil conditions.

(d) Design reports and calculations:
- Hydrodynamic/motion analysis.
- Mooring analysis.
- Model test report with results.
- Design load report.
- Anchor line components: strength and fatigue, including as applicable, detailed design at points of constraints (e.g. in and out of plane bending analysis, in the case of top chain connection).
- Anchor point: strength and fatigue.
- Anchor point holding capacity.
- Fatigue.
- Equipment/ancillaries including the associated equipment, stoppers and fairleads: strength and fatigue.
- Corrosion protection and/or corrosion allowance.

(e) Other information:
- In-service inspection programme and in addition for floating offshore installations at a fixed location:
- Installation procedures.
- Installation records for piles and anchors, *see also* Ch 14,5.
- Plan and schedule for PMS Initial Installation Survey,
- Mooring line components datasheets, inclusive of LR certificate of manufacturing and testing.
- LR certificate of manufacturing and testing of Deck mooring equipment including those used in support of the mooring line failure response plan.
- PMS Initial Installation Survey records.

and in addition for mobile offshore units:
- Anchor point holding capacity.

*1.4.3* An Operations Manual, as required by Ch 1,3, is to be submitted and the manual is to contain all necessary information and instructions regarding positional mooring and, where relevant, thruster-assisted positional mooring. It would normally also contain descriptions of the following:
- Mooring systems.
- Laying the mooring system.
- Anchor pre-loading.
- Pre-tensioning anchor lines.
- Tension adjustment.
- Mooring line tensions/ offset/integrity monitoring.
- Winch/windlass performance.
- Winch/windlass operation.
- Procedure in event of failure or emergency.
- Procedure for operating thrusters.
- Fault-finding procedures for thruster-assist system.
- Maintenance procedures, *see also* 1.4.4.
- Mooring line failure or loss of station keeping capability failure response procedure.

*1.4.4* A PMS Inspection, Maintenance and Repair Manual (PMS IMMR Manual) is to be submitted covering frequency or scheduling, procedures and techniques of such activities for each component, related equipment and support structures. Due

consideration is be given to the Oil and Gas UK Mooring Integrity Guidance. Calibration and testing of monitoring equipment (position monitoring, line integrity monitoring etc.) and associated alarms are also to be addressed. The PMS IMMR Manual is to report pertinent inspection, fault or defect detection, efficiency or degradation measurement methods (and associated error margins or accuracy), ways of recording the results. Inspection records should aim at enabling tracking and trending of degradation processes. This Manual is to address all inspections required for Periodical Surveys.

## ■ *Section 2*
## Survey

### 2.1 General requirements

*2.1.4* The planned survey program is to be reviewed and where necessary updated between each Survey to the satisfaction of the LR Surveyor. A copy of the planned survey program and updates as agreed with the LR Surveyor, as well as survey records, are to be kept for information.

*2.1.5* The inspection and survey records should be used to track and trend the observed degradations or anomalies. A PMS condition track record logbook is to be used to that effect. This is to be updated between each inspection and a copy made available to LR at every Periodical Survey.

*2.1.6* Damage, anomalies and modifications to the positional mooring system should be reported to LR. Unless the design ensures the Offshore Unit and its positional mooring system can withstand a line failure with adequate level of safety (i.e. tension, clearance and offsets still satisfying intact criteria even after one line failed and still satisfying the damaged criteria after failure of second line) the unit shall be considered damaged from the time of the failure.

## ■ *Section 3*
## Environmental conditions

### 3.1 General

*3.1.1* The Owner/Operator or designer is to specify the environmental criteria for which the unit is to be considered. The extreme environmental conditions applicable to the location, or operating areas are to be specified, together with all operating environmental limits. Detailed specialist environmental reports are to be submitted, with sufficient supporting information to demonstrate the validity of the limiting criteria, *see* 3.3.
NOTE: For information on typical industry requirements on specialist environmental reports, “ISO 19901-1, Specific Requirements for Offshore Structures - Part 1 Metocean design and operating considerations” may be consulted. The Class requirements remain those found in the Rules for Offshore Units, especially this section.

### 3.2 Environmental factors

*3.2.1* The following environmental factors are to be considered in the design of the positional mooring system:

- Water depth range, local bathymetry, tidal variations and storm surges.
- Wind, (including gust spectral characteristics and squall characteristics ~~if relevant~~ as applicable).
- ~~Significant w~~Waves (both wind waves and swell) with characteristic heights, periods, spectra and associated parameters.

NOTE: Where applicable, concomitant multiple swell regimes with various frequency and directional characteristics need to be reported

- ~~Wave period.~~
- ~~Wave spectral characteristics.~~
- Current (inclusive of all components, as well as vertical profile).
- Relative angles between wind, wind driven waves and current (and where applicable swell or squall).
- Marine growth.
- Air and sea temperatures.

and in addition for floating offshore installations at a fixed location:

- Sea bed conditions.
- Soil conditions.

*3.2.2* In certain locations the following factors may need to be considered in the design of the positional mooring system:

- Sea ~~I~~ice or icebergs.
- Seismic characteristics and events, such as earthquakes.
- Sea water density (especially in the vicinity of estuaries)
- Snow or ice accretion.

### 3.3 Metocean data

*3.3.2* Data from a calibrated hindcast model covering the service life of the Offshore Unit and providing for each sea state (usually described as 3 hours stationary sea conditions) the data as follows:

- wind sea significant wave height, direction, peak period(s) and other parameters;
- swell sea significant wave height, direction(s), peak period(s) and other parameters;
- wind speed and direction; and
- current speed and direction.

NOTE: The data set should also report spectral formulation and parameters, as necessary. Where applicable, concomitant multiple swell regimes with various frequency and directional characteristics need to be included.

### 3.4 Environmental parameters

*3.4.1* **Water depth**. Minimum and maximum still water levels are to be determined, taking full account of the tidal range, sea bed subsidence, wind and pressure surge effects. For floating offshore installations at a fixed location, data is to be submitted to show the variation in water depth in way of the installation. This data is to be referenced to a consistent datum and is to include, where relevant, the water depth in way of each anchor or pile, gravity base or foundation, pipeline manifold, and in way of the radius swept by an attached ship. The likelihood of sand waves or variation in sea-bed re-settlement at the site shall be documented (*See also* 3.4.10 on sea-bed re-settlement).

*3.4.2* **Wind**. The one-hour wind speed, plus wind gust spectrum, will normally require to be applied in design. The following wind gust spectra formulations can be adopted for the time varying component:

- API RP 2A.
- NPD/ISO
- Other published spectra formulations may be accepted,

*see* Appendix A, A1.2.17.

The site specific environmental data report shall indicate whether the site is subject or not to squalls. In areas where squalls are prevalent, a specialist report is to provide a representative set of squall ~~wind~~ time series data.~~data which includes speed and directional characteristics should also be employed. Estimating wind forces and moments for design input into analysis or model basin wind fields should preferably be done on the basis of wind tunnel tests using an accurate project-specific model.~~ The data should be based on a number of recorded events and extrapolation or scaling techniques are to be documented as well as confidence intervals. Environmental parameters (current and waves) associated with the design squall event (*see* 3.3.1 and 4.3) are to be documented. The report shall address such aspects as directionality, typical development and travel speed. Scaling techniques should be documented and special attention should be paid to the determination of rising slope and decay time in proposed scaled design squall time histories.

*3.4.3* **Waves**:

(a) ~~To ensure that the most critical combinations of low frequency and wave frequency response are determined, a broad range of sea states represented by significant wave heights and peak periods will require to be investigated, preferably based on the use of a 100-year contour (or 50-year contour for mobile offshore units)~~ A site specific specialist report on meteorology, atmospheric and oceanic conditions is required to provide sea state characteristics and data for the location of operation. The sea state characterisation and data is to differentiate, as applicable to the location, between: local wind waves, swell and their combination.

(b) ~~For this approach, a wave contour of significant wave height and peak period combinations will require to be developed, using appropriate extrapolation techniques, to extend shorter term wave height and period joint frequency distribution data. Appropriate methods of developing the wave contour are to be used, *see* Appendix A, A1.2.18~~ Sea state characteristics are to include as a minimum, spectral formulation and associated parameters, significant and maximum wave heights with associated range of peak and zero up-crossing periods.

(c) ~~The method of determining the wave contour is to be documented and included with the design submission package. Where adequate wave height/period joint distribution data is not available to enable such a contour to be produced, a conservative choice of wave period range will require to be applied in the design~~ The data should include contours of equal probability of occurrence of significant wave height and peak period. Appropriate method of developing such wave contours is to be used, *see* Appendix A, A1.2.18. The source data, any extrapolation technique and the detailed derivation of the contours shall be fully documented.

(d) ~~As the wave spectrum is a combination of wind-driven waves and swell, consideration will need to be given for certain locations, to the joint occurrence and angular separation between these two components.~~ For certain locations, the sea conditions may be governed by a combination of local wind-driven waves and remotely generated swell, the specialist report shall provide information on the joint occurrence of wind driven waves and swell. The angular separation between directions of propagation of these two components shall also be informed.

(e) Where the metocean specialist report states that sufficient and adequate wave height /period joint distribution data are not available for the location, the report shall highlight what data is missing to enable such contours to be derived, and indicate alternative source for the missing data. The specialist report shall also propose a conservative range of wave heights and periods combinations for the location and design under consideration.

*3.4.4* **Current**. A specialist report should document current data including ~~Design current velocities~~ velocity ~~are to be established,~~ and direction and their vertical variation through the water depth, taking into account ~~of~~ all relevant components including the following:

- Tidal currents.
- Circulation currents.

- Wind driven current.
- Storm surge generated current.
- loop and eddy currents
- soliton currents.

In general the current data should be calibrated or validated by local measurements.

*3.4.5* **Marine growth.** ~~Account is to be taken in the design of build-up of~~ A specialist report is to document the characteristic data on typical local marine growth, ~~on the anchor lines, riser system and/or the hull, and the resulting increase in load and damping. The thickness of marine growth taken into account is to be stated in the Operations Manual and is not to be exceeded in service~~ such as growth rate, thickness and mass density.

*3.4.6* **Air and sea temperature**. A specialist report is to provide pertinent ~~The minimum and maximum~~ air and sea temperature~~s~~ data ~~are~~ to ~~be specified in accordance with Chapter 1~~substantiate the minimum and maximum air and sea design temperatures criteria for the location of operation in accordance with Ch 1, 4.4.

*3.4.9* **Sea ice and icebergs**. ~~The design philosophy of units intended to be moored in regions subject to sea ice or icebergs will require to be defined, including any quick-release mooring system arrangements.~~ A specialist report (taking into consideration the recommendations and guidance from ISO 19906 as applicable) is to indicate whether the offshore location is prone to sea ice conditions or icebergs drifting. In such areas and where subfreezing temperatures can prevail for a major portion of the year, causing the formation of sea-ice data should be collected to assess the feasibility and establish relevant design criteria.
The data should at least include:

- the seasonal distribution of sea ice,
- the distribution and probability of ice floes, pressure ridges and/or icebergs,
- the effect of ice-gouges on the seabed from icebergs or ice ridges,
- the type, thickness and representative features of sea ice,
- drift speed, direction, shape and mass of ice floes, pressure ridges and/or icebergs, and
- strength and other mechanical properties of the ice.

*3.4.10* **Seismic**. ~~The requirements for units intended to be moored in regions subject to seismic events, such as earthquakes or tsunamis, will be subject to special consideration.~~ For areas that are determined to be seismically active, a specialist report shall document the characteristic seismic activity of the region (for further requirements *see* Chapter 14, Section 1.9). Potential for soil liquefaction or seabed resettlement need to be reported. In shallow water depths, like coastal areas, specialist report shall also consider the seismicity of surrounding regions and indicate whether these could cause tsunamis at the site.

*3.4.11* **Sea water density and salinity**. A specialist report is to document the local water salinity and density variations, (especially in vicinity of estuaries) and their impact on current, corrosion rate etc.

*3.4.12* **Snow or ice accretion**. A specialist report (taking into consideration the recommendations and guidance from ISO 19906 as applicable) is to indicate whether the offshore location is prone to snow or subfreezing temperatures during parts of the year and provide data to substantiate and estimate the extent to which snow can accumulate on the structures and topsides and of its possible effect on the structure.

## ■ *Section 4*
## Design Aspects

### 4.1 Design cases

*4.1.1* The positional mooring system, with or without thruster-assist, is to be designed for the following:

(a) **Intact Case:**

- This case assumes all anchor lines to be effective. Thruster-assist from an approved system can be included, *see* 4.2.

(b) **Damaged Case:**

- This case involves the failure of a single component, i.e., failure of an anchor line or anchor point, or failure of a component in the case of thruster-assist.
- ~~Note that a single failure in the thruster system could lead to stoppage of several, or all, of the thrusters.~~

NOTE:
- a single failure in the thruster system could lead to stoppage of several, or all, of the thrusters. This generally encompasses all non-redundant equipment in the chain of control and power supply to the thruster system or equipment which ensures the good operation of the thruster system.
- loss or flooding of a buoyancy element or clump weight on a mooring line could lead to loss of effective restoring capacity of the line (as well as lead to loss of clearance of the line with adjacent subsea structures).

(c) **Transient Case:**

- The transient case will not normally require to be investigated.
- A transient quasi-dynamic analysis can be used to investigate whether a transient dynamic case requires to be considered in the design. When the maximum line tension and offset from the quasi-dynamic transient case does not exceed the

maximum tension and offset from the corresponding quasi-dynamic damaged case, full dynamic transient load case will not normally be required to be investigated.

*4.1.2* Sensitivity analyses on proposed PMS design are to encompass the level of accuracy of proposed inspection techniques and procedures, tolerances and margins on component properties (inclusive over the service life), as well as installation tolerances. Upon consideration in the design of such variations, the design should still satisfy the requirements of this Chapter.

*4.1.3* A load case considering the failure of any one line adjacent to the first failed line should be run to assess the consequence of such serial failure. The results of the analyses of the positional mooring system with two lines failed should indicate this abnormal configuration does not lead to progressive collapse or incidents of substantial consequences such as loss of life, uncontrolled outflow of hazardous or polluting products, collision, sinking. Mooring line failure response procedure should be referred to from the time one line fails.
The results (offsets, tensions, clearances, etc.) of the two lines failure analyses are to be reported and used to set up the mooring line failure response procedure for the unit.
NOTE:
The mooring line failure response procedures shall include root cause assessment, repair planning, mitigations to limit further damage, ensure safe control of the Offshore Unit after failure of one line and ensure preparedness for further line failure will not have substantial consequences.

*4.1.4* The design shall consider at least three draughts or loading conditions (fully ballasted, fully loaded and one between to attempt capture the most onerous load condition).

**4.3 Design ~~environmental conditions~~ combinations of return periods of environmental parameters**

*4.3.1* Unless agreed otherwise with LR, the following design environmental combinations are to be considered:

(a) For floating offshore installations at a fixed location:
100-year sea state + 100-year wind + 10-year current.
For mobile offshore units:
50-year sea state + 50-year wind + 10-year current.

(b) For floating offshore installations at a fixed location:
100-year sea state + 10-year wind + 100-year ~~(or 50-year for mobile offshore units)~~ current.
For mobile offshore units:
50-year sea state + 10-year wind + 50-year current.

(c) In locations subject to squalls:
For floating offshore installations at a fixed location:
100-year squall + 1-year sea-state + 1-year current.
100-year squall + no other environment.
For mobile offshore units:
50-year squall + 1-year sea-state + 1-year current.
50-year squall + no other environment.

When specialist environment reports adequately provide determined joint probabilities of occurrence of the various local environmental actions (wind waves, swell, wind, current), the design may be based on investigation of the mooring system response to each dominant environmental action with return period of 100 years and associated other actions (e.g. 100 year wind wave plus associated swell, wind and current).

Combinations of environmental parameters of lower return period may govern the response of the positional mooring system and as such combinations of environmental parameters with lower return period may need to be considered to ensure the worst response of the positional mooring system is captured in the design analyses.

In locations where both wind driven waves and swell prevail, the sea state report is to consider the 100 years (or 50 years for Mobile Offshore Units) wind driven waves with associated swell and 100 year (or 50 year as applicable) swell with associated wind driven sea.

In locations subject to cyclonic events the above combinations are to be extended to investigate both cyclonic and non-cyclonic conditions.

~~Joint probabilities of the various environmental actions may be taken into account if such information is available and can be adequately documented.~~

*4.3.2* When the specialist environmental data report indicates stronger correlation between wind, wave and current, (e.g. concurrent occurrence of all environmental parameters at same return period) the above design environmental condition may need to be amended.

*4.3.~~2~~3* For 100-year (or 50-year for mobile offshore units) waves, a range of different wave heights and ~~/~~period combinations ~~will require~~ shall ~~to~~ be considered~~, *see* 3.4.3~~.

(a) To ensure that the most critical combinations of low frequency and wave frequency responses are determined, a broad range of sea states represented by significant wave heights and peak periods will require~~d~~ to be investigated and be

preferably based on the use of a contour of significant wave height and peak period joint frequency distribution at 100-year return period (or 50-year contour for mobile offshore units).
(b) When contours of significant wave heights and peak periods are not reported in the environmental data report, a conservative range of wave heights and period range will require to be applied in the design (*see* 3.4.3(e)).
(c) As the wave spectrum is a combination of wind-driven waves and swell, consideration will need to be given for certain locations to the joint occurrence and angular separation between these two components. Appropriate hindcast data can be used to this effect.
*See also* 3.3.2 and 3.4.3.

*4.3.~~3~~4* For a unit and/or ship designed to disconnect from the mooring system, appropriate lower limiting environmental conditions can be applied for the connected cases.

*4.3.~~4~~5* The mooring system with the unit and/or ship disconnected is normally required to be designed for the criteria specified in 4.3.1 to 4.3.3.

*4.3.~~5~~6* ~~For directional combinations, *see also* 4.4~~ Specific combinations of environmental conditions need to be set as design limits for temporary operations where these operations may overload the positional mooring system in environmental conditions less severe than those considered in 4.3.1 to 4.3.3. The design shall check and confirm that specific operations (e.g. side by side or tandem loading or offloading or connection or disconnection of OU from PMS (disconnectable cases) carried out within specific environmental limits, do not result in overloads in the positional mooring system. The limiting environmental criteria for specific operations should be reported in the operation manual.

*4.3.~~6~~7* ~~For locations where squalls are prevalent and unless otherwise agreed with LR, in addition to cases (a) and (b) in *4.3.1*, sample squall time series data with the peak wind speed in the time series at the 100-year level are to be considered. The return period level of the concomitant sea state and current are to be agreed with LR.~~ Note that account is to be taken in the design of build-up of marine growth on the anchor lines, riser system and/or the hull, and the resulting increase in load and damping.

**4.4 Design ~~D~~directional combinations of environmental parameters**

*4.4.1* Sufficient combinations of directions of wind and current relative to wave direction are to be investigated to ensure the critical cases are found. Swell is to be superimposed from the worst case direction, *see* 3.4.3(d). The following combinations are envisaged as a minimum for design (unless joint directional probabilities of the various environmental actions are available and can be adequately documented or more onerous directional combinations are reported in a specialist report):
(a) Wave, wind and current collinear.
(b) Wind and current at 30° to waves.
(c) Wind at 30° to waves, and current at 90° to waves.
Note
For case (c) above, only combination (a) given in 4.3.1 has to be considered.
For locations where swell direction differs from that of the wind driven waves this directional separation is to be considered.

*4.4.2* ~~When~~ For locations subject to squalls events, squall~~s~~ ~~are~~ are to be considered~~, the time history of the squalls is to include also the variation of the wind direction, *see* 3.4.2. The range of concomitant wave and current directions is to be agreed with LR~~. For all possible directions relative to waves and current unless directionality of squall event is sufficiently substantiated in a specialist report (*See* 3.4.2). The range of concomitant wave and current directions is to be agreed with LR (*See* 4.3.1). At the approach of squalls the directionality of the wind may change rapidly. The resulting transient responses of the offshore unit and its positional mooring system are to be investigated as required.

*4.4.3* For locations subject to cyclonic events, the directionality of the dominant environmental parameters may change rapidly, resulting in transient responses of the offshore unit and its positional mooring system which are to be investigated as required.

**4.5 Environmental directions relative to unit and mooring system**

*4.5.1* For spread moored units, at least head, quartering, beam and down-line directions are to be considered in mooring analysis. ~~Dependent~~ Depending on the symmetry of topside structure, super-structure and positioning mooring system, as well as on response analysis and wind, wave and current force/moment calculations, other directions may require to be considered, *see also* 4.4.

*4.5.2* For weathervaning units, the following cases must be considered as a minimum requirement:
- Wave direction along mooring line.
- Wave direction between mooring lines.

Additionally for locations subject to squalls:
- Squalls blowing in direction along mooring line.
- Squalls blowing in direction between mooring lines.

*4.5.4* For a positional mooring system without thruster assist, ~~two conditions will normally need to be analysed:~~
(a) the single line failure case shall investigate
- loss of highest loaded line leading to highest excursions; and

- loss of second highest loaded line leading to highest line tensions.

(b) the two lines failure case shall investigate:

- loss of either line adjacent to the first failed line.

The assessment of the highest and second highest loaded line are to be based on stable statistics. For asymmetrical mooring configuration due consideration is to be given to the determination of the most onerous line breakage case leading to worst offset and line tension. Additional single and two lines failure cases may need to accounted to check minimum clearances (e.g. in case the worst offset cases do not correspond to the worst clearance). *See also* 4.3.1.

*4.5.5* ~~When squalls are considered, the approach with regard~~ For locations subject to squalls, the environmental directions relative to the unit ~~is~~ are to be ~~agreed with LR~~ based on a specialist report or a full 360° screening to ensure the worst condition is captured. As the direction of the wind during a squall can ~~change~~ significantly and rapidly change, ~~a key consideration is~~ the effect of shift in the wind direction ~~at the time of the peak wind speed~~ as the squall reaches the offshore unit is to be investigated giving due consideration transient shift in heading of offshore units that weathervane.

**4.6 Other design aspects**

*4.6.1* Anchor lines are to have adequate clearance from subsea equipment such as templates, flowlines, ~~etc~~ adjacent fixed structures or other floating units and their subsea equipment. In general a minimum clearance of 10m is to be maintained at all times between the Offshore Unit inclusive of its other mooring lines and all other neighbouring floating, fixed or subsea structures. Acceptability of smaller clearance would need to be substantiated by an appropriate risk assessment. Where mooring line failure could lead to fouling of other structures (e.g. PLEM, pipelines, risers, flow-lines etc) a risk assessment is to be carried out. It is the responsibility of the Owner to notify the local authority or regulator, LR and the Owner of the other structures of the low clearance and any associated risks for the nearby asset. The design shall also check clearance (considering most onerous offset and damaged stability conditions, connection or disconnection operation etc.) between the Offshore Unit and its positional mooring system between components of the positional mooring system or account for the interaction through detailed design.

*4.6.2* The design of the mooring system is to take account of the offset limits required by the drilling string or riser system, and the avoidance of contact between risers and anchor lines or other structures.

*4.6.3* Where normal production, or other normal operational activity, is intended to be continued during periods where an anchor line is disconnected for planned inspection, maintenance or repair etc., specific environmental limitations are to be established to ensure that safety factors are maintained even with one line out of action. Such arrangements and the specific environmental limitations are to be reflected in the Inspection, Maintenance and Repair Manual and Operation Manual. The PMS Inspection, Maintenance and Repair plan is to ensure that scheduling of such IMMR activities be subject to an HAZOP type risk assessment (and account for potential hazard from squall, cyclonic event, etc.).
A similar procedure applies when machinery and equipment cannot remain fully functional during maintenance and inspection.

*4.6.5* In cases where the mooring system is intended to be actively controlled by adjustment of line lengths and tensions, satisfactory evidence must be submitted to show that the adjustment procedure is practical, taking account of winch control and prevailing environmental conditions. The risk associated with such arrangements and operational practice would need to be assessed using HAZID, HAZOP, etc.

*4.6.6* Where units are moored in areas where high velocity currents occur, dynamic excitation due to vortex shedding associated vortex and wake induced vibrations ~~is~~ are to be considered. This will affect both the global response of the Offshore Unit as well as the mean line tensions and the line dynamics of its positional mooring system.
The effects may be more significant as water depth increases.

*4.6.7* ~~Hawse pipes used in the mooring system are to have adequate strength for the imposed loads and when located inside tanks are to be considered for sloshing forces.~~ The mooring line interaction with support structures such as stoppers, fairlead, hawse pipes, guide tubes is to be subject to detailed assessment of actions and reactions between mooring components and the support structure to enable detailed design of the interacting structures.
Aspects such as compression, bending, torque, friction, bearing pressure, grip pressure, chaffing, locking, wear, electrical continuity and effect on corrosion control of the components should be considered and documented as appropriate in the detailed design of the components.

*4.6.8* The maximum allowed thickness of marine growth taken into account is to be stated in the Operations Manual. The actual marine growth should be monitored in service and the plan for regular cleaning (consistent with design assumptions) is also to be included in the Operation Manual. Marine growth is not to exceed the maximum allowed thickness in service.

*4.6.9* When a positional mooring system is found damaged, it shall be promptly reported to the LR and a Condition of Class will generally be recorded. For normal production, or other normal operational activities to continue under Class, the Owner shall reassess the normal operations and demonstrate that the Offshore Unit still meets after damage the level of safety required by Class Rules for intact and damaged (i.e. with one further line failed) conditions allowing for agreed documented mitigation measures (as per mooring failure response procedures) to be put in place. The Offshore Unit operating on Positional Mooring System with one line damage shall not present a risk of major hazard.

*4.6.10* Consideration should be given to providing redundancy in the positional mooring system, to avoid potential disruption of normal production or other normal operation when a single failure or damage is found. This applies to the PMS in general (i.e. mooring lines, mooring equipment, integrity monitoring system and instrumentation etc.).

## ■ *Section 5* Design Analysis

### 5.1 General

*5.1.2* Analytical procedures and numerical methodologies and models used in the analyses are to be described and shown capable of capturing the physical phenomenon pertinent to the specific design. Industry recognised proprietary software or in-house software may be used for the analyses. The original developer is expected to have performed adequate validation and verification of the software, and to readily provide evidence of such validation. In-house software needs to be shown to have been adequately calibrated and validated against model tests data, field measurements, or the results of other already validated industry-recognized software. Indicative accuracy of analytical and numerical tools used in the design analyses of the unit's response are to reported.

*5.1.3* The use of validated numerical tools and software does not generally exempt the design from the need to calibrate and validate the project specific models.

### 5.2 Model testing

*5.2.1* Consideration may be given to dispensing with project specific model tests requirement when the design, is shown to be similar in all design and environmental parameters. The designers shall document and substantiate the basis of request for dispensing with model tests, as well as report the alternative methodology proposed for calibration and validation of the project specific numerical models. Any scaling technique would need to be demonstrated conservative and validated. The request shall be formulated at an early stage of the design and submitted to LR for review and consideration for acceptance.

*5.2.~~1~~2* In general model tests are to address both sea keeping and station keeping aspects. The model test programme and test facilities are to be to LR's satisfaction. The model test programme and specification are to be submitted for review by LR and acceptance prior to the test campaign.
The purpose of the model tests is to be well defined and generally is to enable calibration of key input parameters to the positional mooring system numerical model as well as validation of the results of the numerical models.

*5.2.~~2~~3* The models ~~is~~ are to be of an adequate scale ~~and is to fully represent the moored unit~~ for their intended purpose and fully representative of the features of the Offshore Unit under consideration.
Account is to be taken of the different draughts, trim, deck structures, topside structures and large equipment appendages ~~such~~ as applicable (e.g. anchor racks or thrusters~~. In case of (ultra) deep water moorings, the scale and representation of the moorings will be subject to special consideration~~ fairleads, turret and turntable configuration, risers etc) and appropriate to the type and purpose of the test.

*5.2.~~3~~4* ~~The tests are to be of sufficient duration to establish the low frequency behaviour, and most probable maxima with sufficient reliability.~~ Station keeping model tests, are to represent the positional mooring system main characteristics as closely as practical. Taking into consideration:

- mooring line components stiffness (linear or not),
- mass and inertia properties,
- drag and added mass,
- interaction with sea-bed.

For deep water moorings, the scale and any truncation technique used in the model of the positional mooring system (and risers where their damping contribution may be significant) will be subject to special consideration.

*5.2.~~4~~5* ~~The tests are to include means of establishing the effects of green water and/or slamming, through video recordings of the model testing, and by measurement of the following:~~

- ~~Relative motions.~~
- ~~Forces on local panels mounted at various locations such as bow area and accommodation.~~

It is recommended that preliminary analyses be performed prior to the start of the model test programme, in order to understand and clarify the conceptual design, and to help focus the model testing on the most important design parameters.

*5.2.~~5~~6* ~~It is recommended that an initial analysis be performed prior to the start of the model test programme, in order to understand and clarify the conceptual design, and to help focus the model testing on the most important design parameters.~~
Wave basin tests are to include means of establishing the effects of potential green water, slamming, wave run up, etc. on the design through video recordings of the model testing.
The test should also provide means of observing and assessing behaviour or phenomena that might be specific to the design or operating mode of the Offshore Unit, such as vortex induced motions, motions of the Offshore Unit tandem or side by side moored ships or units.
Measurements may include:

- 6 degrees of freedom motions,

- accelerations,
- mooring line tensions,
- mooring (and riser) loads on turret,
- relative motions (wave to deck elevation).
- forces on local panels mounted at various locations (e.g. bow area, accommodation, exposed decks or horizontal braces, exposed equipment, etc.) to be agreed with LR depending on the specific design.

*5.2.7* Wave basin tests are to be of sufficient duration to establish the low frequency behaviour, and most probable maxima with sufficient reliability.
Wave basin station keeping model tests records are to focus on establishing the main characteristics of responses (e.g. mooring line tensions, offset of Offshore Unit, and turret loads when applicable) such as:

- mean of response.
- standard deviation and distribution of peak values of wave frequency response.
- standard deviation and distribution of peak values of low frequency response.

Most probable maximum values of response should also be estimated.

*5.2.8* Estimating wind forces and moments for design input into analysis or model basin wind fields should preferably be done on the basis of wind tunnel tests using an accurate project-specific model.

*5.2.9* The design philosophy of units intended to be moored in regions subject to sea ice or icebergs is required to be defined,
including any quick-release mooring system arrangements.

*5.2.10* The requirements for units intended to be moored in regions subject to seismic events, such as earthquakes or tsunamis, will be subject to special consideration.

**5.3 Analysis aspects**

*5.3.2* ~~For response analysis, anchor line properties are to be based on the total line diameter including corrosion allowance, *see* Table 10.8.1.~~ The mooring line dynamic behaviour is to be accounted for in the station keeping analyses, taking into account the components mechanical and hydrodynamic characteristic properties such as mass (where appropriate inertia), drag and added mass (where appropriate added inertia) and elasticity.

*5.3.3* Weight and elasticity properties of anchor lines are to be obtained from chain, wire or fibre rope manufacturers. While the mooring chain elasticity can be expected to be linear that of ropes may not be, especially fibre ropes. The non-linear stiffness properties are to be accounted for in the model.
Tolerances of these characteristics are be established and the information is to be documented and included in the submission.
For chain parts of the mooring lines, properties are to be based on the total line diameter including corrosion allowance, *see* Table 10.8.1.

*5.3.4* The sensitivity of the simulated positional mooring system and the response of the Offshore Unit to these tolerances on line properties (inclusive of expected variations of these over the service life, effect of corrosion, and marine growth) are to be carried out to ensure the resulting responses remain within acceptable limits (e.g. Offset Limit, factor of safety on mooring line strength, clearances). Similarly the analyses are to investigate the sensitivity of responses to variations in assumed drag and inertia coefficients of the mooring lines.

*5.3.5* The effect of mooring line interaction with soil is also to be taken into account in the station keeping analyses. Consideration is to be given to the local bathymetry, sea-bed slope (or specific profile), sand wave phenomena (and associated changes in mooring line seabed support and embedment), friction (in-line and lateral) between the line and potential in service scouring or dig-in in the touch down region.
Sensitivity of the simulated positional mooring system and the response of the Offshore Unit to these soil-mooring line interactions (that may occur over the service life) is to be carried out to ensure the resulting responses remain within acceptable limits (e.g. Offset Limit, factor of safety on mooring line strength, clearances).

*5.3.6* The offshore unit station keeping analyses is also to take into consideration manufacturing (e.g. length, stiffness) and installation tolerances (e.g. anchor location, potential remaining slack in the line after installation or in inverse catenary of the buried line section close to the anchor) as well as precision and accuracy of survey/inspection techniques intended to be deployed in service to confirm the positional mooring system configuration and integrity.
The positional mooring system design is also to ensure that the simulated positional mooring system and the responses of the Offshore Units remain within acceptable limits (e.g. Offset Limit, factor of safety on mooring line strength, clearances ) when these uncertainties are considered.

*5.3.7* When, after installation, the positional mooring system, Offshore Unit, structure and equipment etc. are found to significantly differ from what was accounted for in the design, as-installed station keeping analyses will need to be carried out to confirm compliance with these Rules.

*5.3.8* For positional mooring systems using fibre ropes, analyses methodologies are to be submitted to LR for acceptance. The recommendations of API RP 2SM are to be taken into account in analyses methodologies to ensure conservative estimates of mooring line tensions and the offsets of the offshore unit. Due attention is to be paid to the non-linear dynamic behaviour of

the ropes, frequency dependent stiffness characteristics and the delayed elastic stretch and delayed elastic recovery characteristics of the ropes. The analyses are to investigate the sensitivity of the responses to these input parameters.

### 5.4 Analysis

*5.4.1* The following analyses, which may be combined, are to be carried out and submitted to LR:

- Hydrodynamic analysis of the offshore unit.
- Heading analysis (for Offshore Units that weathervaning about single point mooring or whose heading significantly varies with environment directionality and conditions).
- Motions analysis of the moored unit.
- Mooring analysis.

~~*5.4.2* The following data has to be derived from the analyses:~~

- ~~Steady force offsets, and tensions, from wind, current and wave drift.~~
- ~~Wave frequency motions/accelerations.~~
- ~~Low frequency offsets and tensions from 2nd order wave drift forces, and wind gust effects.~~

~~*5.4.3* Time domain or frequency domain analysis methods can be applied. The basis for linearisation of the frequency domain analysis is to be documented.~~

*5.4.2* Hydrodynamic analysis is required to establish the six degrees of freedom motion response amplitude operators (RAOs) of Offshore Units.
The response amplitude operators (RAOs) of the six degrees of freedom motions should be determined, covering a range of frequencies encompassing the wave spectra pertinent to the project (with sufficient refinement in increment around natural periods of responses) and headings covering 360° (unless symmetry can be used).
In general at least three different drafts or loading conditions should be considered taking due account of the site specific water depth. Table 10.5.1 illustrates such practice.
The six degrees of freedom motion RAOs are input to heading, motions and mooring analyses.
Generally the hull of large offshore units should be modelled with 3D-diffraction elements and validated first order radiation-diffraction numerical software can be used in the derivation of the RAOs of the six degrees of freedom motions of the offshore unit. While for simple catenary mooring line configurations in shallow to medium water depth configurations, the positional mooring system can generally be assumed to not significantly affect the first order motions of the offshore unit, such assumptions may not apply to offshore units in moored in deep water or when using semi-taut to taut mooring lines configurations. Thus the validity of such assumptions are to be checked and, when necessary, coupled analysis be used.
Note: RAOs of motions from linear radiation-diffraction analyses are used as input to heading, motions/offset and mooring analyses. The RAOs generally only consider potential damping and as such, when looking at actual responses, viscous damping contributions from such effects as skin friction, vortices etc. needs to be input separately in heading, motions, mooring analyses. The additional damping input shall be documented.

**Table 10.5.1 RAO Parameters**

| | From | To | Increment | Notes |
|---|---|---|---|---|
| Frequency (rad/s) | 0.1 | 1.5 | ≤ 0.05 | Refinement around natural periods to be considered. |
| Heading (degrees) | -180 | 180 | ≤ 10 ~~(see Note 1)~~ | Linear interpolation. Refining around singular headings. |
| Loading Condition | Fully Loaded | Ballasted | At least one intermediate | Most onerous conditions in service and transit conditions to be considered. |

*5.4.3* Heading analysis is generally used in load response analysis in the structural assessment of weathervaning ship type offshore units as part of the LR ShipRight Procedure for Ship Units to establish response parameters and design waves. It may also be used in support of motions and mooring analyses to assess the mean heading of the unit relative to environment parameters to be used in the station keeping analyses and fatigue analyses.
It requires a set of hindcasted environmental data (*see* 3.3.2).
The mean heading of the unit is to be calculated for each sea-state considering the action of the wind sea, swell, current and wind. The hull is to be modelled with 3D-diffraction-radiation elements at a minimum of three draughts representative of all loading conditions. The effects of current, drag loads and wind loads on the hull should be represented by current force coefficients and wind force coefficients. The current force coefficients should be derived from model tests (or the OCIMF data [Mooring Equipment Guidelines] when applicable). The wind force coefficients should preferably be based on values from model test results (for ship shape hulls preliminary analyses may use wind coefficients from the OCIMF data [Mooring Equipment Guidelines] corrected as appropriate for topsides structures).
For offshore units with thruster assisted heading control, both fully operational and single failure is to be considered.

The following information on the directionality of the environment relative to the offshore unit can generally be derived and used to substantiate the conservatism of the directional combinations of environmental parameter proposed in 4.4.1 and assist in the selection of fatigue design load cases:

- relative direction of the offshore unit and environmental parameter (wind, wind driven waves, swell, current)
- sea state Mean and Standard Deviation, Skewness and Kurtosis of Relative Heading as a function of Significant Wave Height
- (differentiating swell and wind driven waves)
- wind sea direction against wind sea Hs;
- swell sea direction against swell sea Hs;
- wind direction against wind speed;
- current direction against current speed.

*5.4.4* Motion analyses of the moored unit focus on assessing the characteristic motion response of the Offshore unit within envelopes of design environmental conditions, *see* Section 4.
The analyses are to investigate a large set of stationary (typically 3 hours) environmental conditions to enable the estimation of maximum offsets (horizontal motions primarily associated with surge, sway and yaw of the unit) but also the maximum heave, roll and pitch.
As may be required by the specific positional mooring system and offshore unit design and operations, the motion analyses may also need to focus and investigate motions in relation to specific criteria such as clearance criteria (e.g. for external turret moored units potential overshoot in surge motion requires special consideration).
The model for the motion analysis should include restoring characteristics and damping contributions from:

- Positional mooring system.
- Thruster system.
- Risers or umbilical system

The motion analysis should generally be based on time domain simulations. Frequency domain analyses may be acceptable when non-linear or coupling effects are not significant, subject to sufficient model test or field data calibration confirming the validity of the analysis and agreement with LR.
When linearization techniques are used they should be fully documented and shown to have insignificant impact on the motion responses for the environmental conditions considered.

The following component of the global motion responses shall be derived from the analyses:

- mean offsets from wind, current and wave drift steady force loads.
- low frequency offsets from 2nd order wave drift loads, and wind gust loading (and when significant the associated accelerations).
- wave frequency motions and accelerations from oscillatory response of the unit to the first order wave loads.
- vortex induced motions induced by flow over slender or sharp edged structures (*see* 4.6.6).

The effect of the mooring system on the first order wave frequency motion responses may generally be ignored (for positional mooring systems using loose catenary mooring line configuration in shallow to medium water depth). Similarly the effect of riser and umbilical systems on the first order wave frequency motion responses may generally be ignored for traditional compliant configurations in shallow to medium water depth). These effects may become significant in deeper water in which case, coupled analyses should be conducted to verify the motion responses for the estimate of maxima.
When part of the hull of the offshore unit is slender, small in comparison to wave lengths to be considered, or presents sharp edges, viscous effects are to be considered and included in the analysis. For example on ship shape hulls, linearised roll damping should be calculated for each sea-state using a published method and the results verified with model tests.
Low frequency motion responses occurring close to the natural frequency (e.g. surge motions of ship-shaped FPSO) are quite sensitive to damping contributions from mooring lines and risers. These should be accounted for in the analyses, generally including the effect of line dynamics to the analysis. Damping input to the analyses model, its calibration and validation against pertinent model tests or full scale data should be reported in detail.
Local constraints to the sea water or wind flow or obstacles in the vicinity of, or attached to, the offshore unit or its moorings that may cause interferences should be given special consideration.

*5.4.5* Mooring load analyses are to address both loads acting on mooring lines (and their components) and loads the mooring lines impart on support structures of the offshore unit and mooring line attachment points.
The resulting loads for each stationary environmental condition considered should be described in terms of their steady mean component, low-frequency component and wave frequency component.
The oscillatory component should be statistically described with standard deviations and distribution of peak responses and enable the estimate of maximum (or minimum values).
Results should include in-line tensions, but also where necessary at component interfaces forces and moments. The analyses should enable derivation of the loads (forces and moments) acting on components, as required for input to the detailed design of the components.
Mooring load analyses are often combined with motion analyses of the moored unit as the characteristic motions of the mooring lines attachment points on the unit are required to be modelled to the same extent as can be derived from the motion analyses of the moored unit.
Mooring load analyses should provide all necessary load characteristics for the verification of the mooring lines global performance and detailed design of the mooring line components and support structures.
The mooring load analyses are generally to be carried out in time domain to capture the non-linear dynamic behaviour of the lines.
The main non-linearities in the mooring line responses typically arise from:

- large changes in the line geometry as it stretches, (inherent to catenary configuration or lines with buoyancy elements).
- axial stiffness of the components (e.g. fibre ropes).
- viscous fluid flow interaction (through drag and added mass) with mooring line components.
- soil interaction effect through axial and lateral friction effects on line motion on the sea bed.

Frequency domain analyses may be acceptable when non-linear or coupling effects are not significant, subject to sufficient model test or field data calibration confirming the validity of the analysis and agreement with LR.
When linearization techniques are used they should be fully documented and shown to have insignificant impact on the load responses for the environmental conditions considered.
The mooring lines model should be representative of the weight and buoyancy, geometric, mechanic and hydrodynamic properties of the various components and their assembly.
The mooring line layout should take into consideration the location of the anchor points to the sea bed, as well as the location of the attachment point on the unit and mooring line pretensions, the unit's draft, water depth and seabed morphology.
The mooring lines component drag and inertia characteristics can generally be modeled using a Morison formulation.
Due consideration should be given to potential onset of vortex shedding along the line and associated loads and vibrations arising from these. This can significantly affect drag characteristics of the mooring lines.

*5.4.6* For offshore units operating in areas subject to squalls special consideration should be given to the transient nature of the load and motion responses. Generally squalls are considered to reach the moored offshore unit from any direction at any time during otherwise stationary environmental conditions. The analyses should investigate a sufficient number of squall cases (for various squall time traces) to enable to establish maxima of responses. While such analyses require substantial number of cases to be considered, the analyses duration needs only to be sufficient to capture the transient squall wind loading and associated response of the moored unit. Care should be taken to ensure that the peak responses are captured.

*~~5.4.4~~5.4.7* For low frequency response analysis, the non-linear stiffness characteristics are to be satisfactorily represented.
The amplitude of low frequency motion will be highly dependent on system damping from the following:

- Current.
- Wave drift.
- Viscous effects on the hull.
- Anchor lines and risers.
- Wind effects.

Thruster damping may also be applicable in relevant cases and the basis for the damping terms used in the analysis is to be documented and submitted.

*~~5.4.5~~5.4.8* Tensions due to low frequency and wave frequency excitation can be computed separately. The effect of line dynamics is to be accounted for in wave frequency analysis. Low frequency tension can be based on quasi-static catenary response. Wave frequency dynamic line tension is to be computed at alternative low frequency offset positions, *see* 5.5.4.

*5.4.9* For dis-connectable positional mooring systems, analyses are required to simulate the transient connection and disconnection operations to ensure the responses (e.g. loads, slack, motions, clearances, potential overshoot or run-up etc.) are within design envelopes (*See also* 4.3.6). Similar model as for motion or mooring analyses can be used. Generally the analyses should capture the various stages and configurations of the positional mooring system during such operation, cover a representative range of environmental conditions in which the operation may be initiated at any time. The transient nature, speed and duration of the operation should be taken in consideration in the analyses, as well as the level of controls (e.g. uncontrolled quick disconnect or control disconnect, re-connect), the load transfer, progressive coupling, decoupling of the Offshore Unit and its positional mooring system etc.

**5.5 Combination of low and high frequency components – Design values**

*5.5.1* Maximum design values for offset and tension are ~~preferably~~ to include nominal pre-set static values, steady component, and wave and low frequency contributions derived from combined wave frequency and low frequency dynamic response analyses. The time domain simulations are to be of sufficient length to establish reasonable confidence levels in the predictions of maximum response. When squalls are considered, the approach for selecting the design values of tensions and offsets is to be agreed with LR.

*5.5.2* Symmetry of the positional mooring system can be accounted for in the estimation of maximum design values of offset and mooring line tensions to reduce the number of maximum design values to be considered in the design verification.

*5.5.~~2~~3* The most probable maximum values for tension and offset can be determined from the distribution of peak loads. The statistical basis and probability distribution (Rayleigh, Weibull, Gumbel, etc.) ~~being applied to derive the probability distribution is~~ fitted to the peak responses from the analyses to derive the design maximum values is to be documented and submitted for review. For each response considered the expected average of maxima of multiple simulations and associated standard deviation, and the probability distribution used in the derivation of the most probable maxima are to be demonstrated to provide a good fit to the peak values.
Sensitivity of the maximum design values to the underlying assumptions (number of peaks, threshold etc.) should be documented.
When fitted distributions are not well defined or assumptions are not verified (e.g. narrow banded process assumption) a robust estimate expected maximum value (derived from multiple seed analyses) should be referred to in the design.

# Part 3, Chapter 10

*Existing paragraphs* 5.5.3 *and* 5.5.4 *have been renumbered* 5.5.4 *and* 5.5.5*.*

## ■ *Section 6* Anchor lines

**Effective date 1 July 2015 and Corrigendum**

### 6.1 General

*6.1.1* Anchor line length is to be sufficient to avoid uplift forces occurring at the anchor point for damaged condition loads, unless the anchor point is specially designed to accept a vertical component of loading.

*6.1.2* An anchor line integrity monitoring system or device is to be provided for floating unit mooring systems, to detect line breakage and significant tension and offset irregularities under ambient environmental conditions as well as more severe storms within the envelope of design environmental conditions.
The mooring line integrity monitoring system shall be able to detect failure of any part along the line (between attachment point to Offshore Unit to at least the seabed touch down or embedment point.
Ability to detect line failure beyond seabed touch down or embedment should be assessed and documented. The results should be taken into consideration when setting the scope of Offshore In Water Survey.
The precision and accuracy of the system is to be documented for a load range up to at least 90% of the breaking strength of the mooring lines and 100% of the offset range.
Detection of tension anomalies or line breakage is to raise an alarm (at least visual). The system should be able to be interrogated on demand and present sufficient redundancy so that the system remains operational after failure of any one component and to enable inspection or testing, maintenance and repair without loss of operability.
Calibration checks are to be carried out at least once a year.
Calibration and maintenance procedures and schedule are to be documented in the Operation Manual of the unit.
This is generally not a requirement for offloading buoy systems.

*6.1.3* Specific ~~S~~steel wire rope, ~~and~~ chain and fibre rope design requirements ~~are defined~~ can be found in Sections 7, ~~and~~ 8 and 9 respectively.

*6.1.4* In general, the break strength of the anchor line is not to be greater than the load bearing capacity of the connecting structure~~,~~.
For chain or rope loose fittings, sockets, shackles, connectors etc. the design shall be based on mooring line pull at least equal to the as new nominal minimum break strength of the mooring line main component (steel wire rope, chain or fibre rope) applying a minimum contingency factor of 1.1.
For fairleads and stoppers *see* Ch 10.10. For support structure *see* ~~*also*~~ Pt 4, Ch 6,1.

*6.1.5* In general the mooring analyses should provide all of the loading parameters required for the detailed design of the mooring lines components and the associated supporting structures they interact with (pad-eyes, fairleads, bend shoes etc). The detailed structural or mechanical design of complex or non-standard (e.g. special D-shackles with dimensions not conforming with ISO 1704, or special connectors) component is generally substantiated by finite element calculations. Suitable elastic plastic models need to be used to model elastic plastic behaviour (e.g. Ramberg-Osgood law) at the contact points. Convergence should be demonstrated for the large displacement nonlinearities, contact related nonlinearities as well as nonlinear material properties. Alternatively elastic analysis is also acceptable.
The detailed design calculations of components should address both strength and fatigue aspects. For fatigue calculations principal stresses at the model mesh are to be refined at hot spots locations and at surface of the modelled component to ensure characteristic mean principal stresses in the surface plane are captured.
Special non-standard mooring components shall be designed so that local yielding only occur for a few load cycles imparting a shake-down effect after which no further yielding occurs. The analysis shall be based on cyclic material properties and cyclic loading shall demonstrate an effective shakedown after few cycles.
Deformation under design loads from (intact and one line damage case) shall not adversely affect the performance of the component.
Conservative plastic strain and stress curve and characteristics plastic strain limit shall be reported for the selected material with reference to recognised code or standard and substantiated by material test records.

*6.1.6* Kenter links are not permitted on long term permanent mooring systems. Connectors purposely designed (for project specific strength and fatigue loading) (e.g. H-Links) and manufactured under LR Survey shall be preferred.

*6.1.7* Locking mechanisms of pin parts of mooring line component connections on long term positional mooring systems should be redundant and not be located within the main load path.

### 6.2 Factors of safety – Strength

*6.2.1* Minimum factors of safety applicable to the steel wire rope, ~~and~~ chain and polyester anchor lines of moored floating units are given in Table 10.6.1. For fibre ropes, *see* 9.2.2.

**Table 10.6.1 Minimum factors of safety for anchor lines for floating offshore installations at a fixed location**

| Design Case | Factor of safety, *see Note 2* | |
|---|---|---|
| | Intact | Damaged |
| Extreme storm, or maximum environment, with floating unit attached | 1,67<br>*See Note 1* | 1,25<br>*See Note 1* |

NOTES
1. The factors of safety given in this Table are associated with the following conditions:
   (a) Arrangements being available to shut down production and/or transfer of oil or gas through risers in event of anchoring system failure.
   (b) The floating unit being located in an open sea area. Special consideration will be given to factors of safety when the unit is in close proximity to another installation, or is located near the shore.
2. Factor of safety = $\dfrac{\text{Anchor line minimum breaking strength}}{\text{Maximum tension}}$
   Anchor line minimum breaking strength basis to be documented.
   A reduction factor may require to be applied to the standard assigned minimum breaking strength of anchor line components in some cases (e.g., where component test database is small: for non-standard components), or where anchor line components are not new.
3. Maximum tension to be based on assessment by dynamic analyses. *See also* Section 5.5.3 on maximum tension.

*6.2.2* Factors of safety applicable to the steel wire rope, ~~and~~ chain and polyester anchor lines of offshore loading buoys (CALMs, turret mooring buoys which may remain temporarily disconnected without mooring line integrity monitoring etc.) are given in Table 10.6.2. For generic fibre ropes, *see* 9.2.2.

### 6.3 Fatigue life

**Table 10.6.2 Minimum factors of safety for anchor lines of offshore loading buoys**

| Design Case | Factor of safety | |
|---|---|---|
| | Intact | Damaged |
| Extreme storm, or maximum storm condition with ship attached | 1,85 | 1,35 |

NOTES
1. For special cases where allowable offset criteria for risers cannot be met in a Damaged Case (single line break) (e.g.~~,~~ in offshore loading buoy systems for shallow water), the Damaged Case can be omitted in design and an increased intact factor of safety applied. A minimum factor of safety of 2,3 is to be applied in this case. Failure of any one mooring line should still be shown not lead to progressive collapse or incidents of substantial consequences such as loss of life, uncontrolled outflow of hazardous or polluting products, collision, sinking.

2. Maximum tension to be based on assessment by dynamic analyses. *See also* Section 5.5.3 on maximum tension.

**Table 10.6.3 Factors of safety for PM notation**

| Design Case | Description | Factor of safety for **PM** notation, *see Note 1* | |
|---|---|---|---|
| | | Quasi-static analysis | Dynamic analysis |
| 1 | Operating (Intact) | *2,7* | 2,3 |
| 2 | Survival (Intact) | 1,8 | 1,5 |
| 3 | Operating (Single line failure) | 1,8 | 1,5 |
| 4 | Survival (Single line failure) | 1,25 | 1,1 |

NOTES
1. The factors of safety given in this Table apply to units positioned at least 300m from another unit.
2. The unit is to be positioned to avoid contact with another unit in any of the design cases.
3. *See also* Section 5.5.3 on maximum tension.

**Table 10.6.4 Factors of safety for PMC notation – Quasi-static analysis**

| Design Case | Description | Factor of safety for **PMC** notation Quasi-static analysis, *see Notes* | | | |
|---|---|---|---|---|---|
| | | Unit moored 50 m or less from other structures | | Unit moored within 50 m to 300 m from other structures | |
| | | Critical line | Non-critical line | Critical line | Non-critical line |

| | | | | | |
|---|---|---|---|---|---|
| 1 | Operating (Intact) | 3,0 | 2,7 | 3,0 | 2,7 |
| 2 | Survival (Intact) | - | - | 2,0 | 1,8 |
| 3 | Operating (Single line failure) | 2,0 | 1,8 | 2,0 | 1,8 |
| 4 | Survival (Single line failure) | - | - | 1,5 | 1,33 |

NOTES
1. *See also* 5.4.
2. The unit is to be positioned to avoid contact with another unit in any of the design cases.
3. *See also* Section 5.5.3 on maximum tension.

*6.3.2* Where applicable tension bending ~~fatigue calculations at fairlead/stopper~~ effects are to be considered (~~e.g., for taut-leg mooring systems)~~ in the fatigue calculations of the mooring line at the fairleads and stoppers (or at any point within the line where it is subject to a constraint resulting in local bending). The detailed methodology shall be reported and agreed with LR in the early stages of the design. Contingencies should be included to address any uncertainties.
Torsion in the mooring line shall be avoided by design. In cases where this is not possible the performance of the component under such loading regime should be substantiated by a qualification programme agreed with LR.
Note: For top chain connections to stoppers, guidance can be drawn from publications from recent joint industry research projects on Fatigue of Top Chain of Mooring Lines due to In-Plane and Out-of-Plane Bending). Details of the methodology shall be reported and agreed with LR at early stage of design. The associated scope of manufacturing and testing shall be agreed with LR. The bushing performance shall be well documented and substantiated by adequate prototype testing and confirmed by factory acceptance tests. The design shall include contingencies to address any uncertainties (e.g. long term performance of bushing, bush and interlink friction coefficients etc.).
*(see also* Section 10.1.11*).*
Applicable factors of safety shall be agreed with LR, after review of the detailed design methodology (else the default is 10).

*6.3.3* Fatigue life calculations for anchor lines can be carried out in accordance with a recognised Code, e.g.~~,~~ API 2SK*: Recommended Practice for Design and Analysis of Stationkeeping Systems for Floating Structures.*
NOTE:
Where various wind driven wave and swell (potentially multiple) regimes prevail concurrently, the fatigue assessment shall be shown to account for these environmental characteristics and conservatively capture the various peak frequencies and relative directionalities.

*This paragraph shows one corrigendum amendment.*

*6.3.5* The minimum factors of safety on the calculated fatigue lives for components of the mooring system are to comply with Table ~~6.5.2~~ 5.5.2 in Pt 4, Ch 5 .

## ■ *Section 7*
## Wire Ropes

### 7.1 General

*7.1.1* This Section applies to steel wire ropes for ~~offshore~~ positional mooring systems of offshore units.

*7.1.2* Wire ropes, ~~and~~ associated fittings, are to be of an approved design.

### 7.3 Design verification

*7.3.1* The design of wire rope and associated fittings is to be verified. The following information will be required for appraisal and information:

- Plans of rope assembly, components and fittings such as terminations/sockets, bearings, pins and locking mechanism, bend stiffeners, electrical insulation and other fittings.
- Materials specification covering all components and fittings, steel wires, steel fittings, pins, socketing resins, sheathing and blocking or lubricating compound).
- Corrosion control specification (anodes, steel wire galvanisation, coating, electrical insulation, arrangement, and supporting calculations.
- Design specification.
- Purchaser's specification.
- Codes and Standards applied.
- Calculations for the strength and fatigue of rope, socket, fittings, and their corrosion protection.
- Dimensions of rope assembly and components and fittings as well as associated tolerances.
- Weight properties and tolerances (to include weight per metre of main rope section inclusive of sheathing).
- Axial and torsional stiffness data.

- Wire rope datasheet (inclusive of all rope main characteristics, tolerances, handling and service limiting criteria).
- ~~Torsional stiffness data.~~

*7.3.2* Data from prototype rope tests is to be ~~made available as required~~ submitted (inclusive of material, construction and test procedures and data).

*7.3.4* The minimum factors of safety on the calculated fatigue lives of wire rope and fittings are to comply with Table ~~6~~5.5.2 in Pt 4, Ch 5, 5.6.

*7.3.5* The rope termination including the socket, socketing arrangement and pin is to be designed to withstand a load of not less than the minimum breaking strength of the attached wire rope and be shown to withstand no significant plastic deformation under loading equal to 80 per cent of this load.
The rope is to be designed for the maximum design, storage and installation conditions specified for the project.

*7.3.6* Pin locking mechanism, anodes and bend stiffeners attachment to the sockets should not be in the main load carrying path of the socket.

*7.3.7* Sheathing should be able to match and accommodate the rope flexure and elongation under rope design and service loads without loss of integrity. The sheathing should not rotate in relation to the sockets and be designed for the maximum grip pressure under various tensions specified for the project.

*7.3.8* Bend stiffeners and their connection to sockets shall be designed to protect the wire rope end termination from over bending under design loads (including storage, installation and service) for the range of off line pull angles or curvatures specified for the project.

*7.3.9* Bend stiffener connections to sockets should be adequately protected against corrosion.

**7.5 Corrosion protection**

*7.5.5* Polyethylene sheathing can also be used on appropriate rope constructions, as an addition to, but not normally as an alternative to, galvanising:
(a) Where sheathing is intended to be fitted, the specification is to be submitted. ASTM D 1248 is an acceptable specification for medium or high density polyethylene sheathing.
(b) A continuous strip of contrasting colour is to be incorporated into the sheathing to aid monitoring for twist. The position of the strip around the circumference sheathing in relation to a reference point on each end socket should be reported on plan.

*7.5.6* Compound used as blocking or lubricating material shall as a minimum meet the requirements ISO 4346 Steel Wire Ropes for General Purposes - Lubricants - Basic Requirements or equivalent.

*7.5.7* Compound must not adversely affect the long term integrity of the wires and sheathing.

**7.6 Manufacture and testing**

*7.6.1* Steel wire ropes are to be manufactured in accordance with the design standards and procedures and at a works approved by LR. Ropes and fittings will be subject to LR survey during manufacture and testing.
A prototype testing programme is to be agreed with LR and carried out under LR survey. Prototypes are to be of the same materials, construction and termination unless specifically agreed with LR.

*7.6.9* The tests required by 7.6.8 are to be as follows:
(a) The modulus test is to be carried out on one finished rope sample taken from the first production length. Production sockets need not be fitted for this particular test. Load/extension characteristics and permanent stretch are to be determined and documented.
Acceptance criteria for permanent stretch ~~is~~ are to be as follows:
- Maximum of 0,4 per cent for spiral strand and locked coil ropes.
- Maximum of 0,8 per cent for six-strand ropes.

The modulus of elasticity is to be calculated and documented. The basis for the calculated value (cross-sectional metallic area, or area of circle enclosing the rope) is to be clearly stated.
(b) Breaking load test is to be carried out on one sample taken from each manufactured length.
- Where the rope design, the machine, and the machine settings are identical, consideration can be given to a reduction in the number of tests. As a minimum, breaking load tests are to be carried out on a sample taken from each of the first manufactured length, and one other length, selected by LR Surveyors.
- Tests are to be carried out in accordance with a recognised National Standard such as ~~DIN 51201~~ EN 12385-1 Steel wire ropes – Safety – Part 1: General requirements (method 1).
- One of the rope samples is to be fitted at one end with socket and pin taken from the project production batch, and socketed in accordance with approved procedures (guidance from EN 13411-4 Terminations for steel wire ropes – Safety – Part 4: Metal and resin socketing). Where more than one socket design type is involved, a further assembly is to be tested for each different type of socket.
- The rope sample and the production socket are to withstand the specified minimum breaking load.

The socket pin is to be able to be removed after the test, and replaced, without the application of undue force.

- NDE to be carried out on the socket following testing (100 per cent visual and 100 per cent MPI).

*7.6.10* Socketing is to be performed according to the quality plan and is to follow a tested and repeatable procedure drawing on ISO 17558 ‘Steel wire ropes - Socketing procedures - Molten metal and resin socketing’ and be carried out by experienced personnel.
Due attention should be paid to the following parameters:

- rope termination brush configuration,
- cleanliness of socket and rope brush,
- resin mix and mixing technique,
- brush and socket positioning and alignment,
- resin pouring technique,
- control of temperature and duration of curing,
- scale effect.

*7.6.11* The characteristic mechanical properties (e.g. modulus of elasticity, shrinkage, compressive strength) of the socketing resin shall be established from a number of test samples. Guidance on tests methods can be drawn from BS 6319 Testing of Resin Compositions for Use in Construction (especially Part 1, 2, 5 and 12).

- resin compressive strength and modulus of elasticity (also ISO 604 Plastics – Determination of compressive properties).
- shrinkage
- density and hardness (also EN 59 Glass reinforced plastics – Measurement of hardness by means of a Barcol impressor).

The number of test samples is to be such as to establish the properties with sufficient confidence.

*7.6.12* Bend stiffeners are to be manufactured according to a quality plan and follow a qualified and repeatable procedure. Material properties (e.g. tear strength, elasticity, water absorption, aging) are to be reported.

*7.6.13* The maximum allowable curvature of the wire rope under storage, service and installation conditions are to be substantiated and documented by the manufacturers.

*7.6.14* Material properties (e.g. elasticity and water absorption) of the sheathing are to be documented.
The sheathing should be manufactured such that it does not rotate in relation to the wire rope and sockets.
The manufacturer is to substantiate and report curves of maximum allowable grip pressure under various tensions for the sheathed rope provided.

*7.6.15* Complete rope assembly characteristics and associated tolerances are to be documented.

## ■ *Section 8*
## Chains

### 8.1 Chain grades

*8.1.1* Chains to be offshore Grades R3, R3S, ~~or~~ R4, R4S or R5 (*see* 8.1.2) and are to comply with Ch 10,3 and Ch 10,4 of the Rules for Materials, as applicable. Acceptance of other grades will be subject to special consideration.

*8.1.2* Acceptability of chains of material grade R5 will be given special consideration and be subject to satisfactory qualification testing of the chain for validation of the API RP 2SK tension-tension fatigue curve by the manufacturer.

*8.1.3* The maximum allowable tensile yield strength for the grade considered is to be agreed with the purchaser and documented for each project.
When the minimum tensile yield strength specified in Chapter 10 of the Rules for Materials is exceeded by more than 3 per cent of the specified minimum value for the grade considered, the purchaser is to be notified and the actual yield strength from tests to be reported.

### 8.2 Corrosion and wear

*8.2.1* A size margin over and above the minimum chain size required to satisfy Rule factor of safety requirements is to be included to allow for the corrosion and wear which can occur over the intended service life of the anchor chain or associated component. The minimum margins shown in Table 10.8.1 are recommended.
Note: These rates are minimum recommendations. The actual rate of corrosion should be monitored during successive periodical surveys to access the necessity to replace the chains in case accelerated corrosion or excessive pitting is observed. It should be noted that in tropical and subtropical regions as well as some coastal areas much greater rates of corrosion (sometimes exceeding twice these rates through localised pitting) have been observed. The Owner is to specify their corrosion protection strategy and may specify a larger minimum rate of corrosion for specific projects, taking due account of the region of operation of the unit.

### 8.3 Additional specific requirements

*8.3.1* The purchaser is to specify the project specific material, manufacturing and testing requirements where these complement, exceed or are more onerous than those of Chapter 10 of the Rules for Materials (e.g. chain length and tolerances, maximum yield strength, coating, reference link identification).
These shall be reported and agreed with LR.

*8.3.2* A datasheet is to summarise all characteristics of each chain segment as necessary to ensure satisfactory deployment of the chain within the Positional Mooring System and to support the in service inspection, repair and maintenance plan.

## ■ *Section 9*
## ~~Provisional requirements for f~~Fibre ropes

### 9.1 General

~~*9.1.1* This Section gives provisional requirements for fibre ropes used in positional mooring systems. The requirements apply to fibre ropes incorporated as follows:~~
~~(a) **Catenary mooring system**:~~
- ~~Fibre rope insert lines, these being confined to the suspended part of the catenary system. Chain or wire rope will be fitted in parts of the anchor leg subject to contact with sea bed or floating unit.~~

~~(b) **Taut-leg moorings**:~~
- ~~In this case, fibre rope will form the majority of the anchor leg's length. System compliancy will come from the inherent extensibility of the fibre rope. Chain will be fitted at upper and lower parts of the taut leg, where hard contact can occur.~~
- ~~Special consideration will be given to other types of fibre rope mooring application.~~

*9.1.1* This Section gives requirements for fibre ropes part of loose or semi-taut catenary mooring lines of positional mooring systems of offshore units.
The use of fibre rope is confined to the suspended immersed part of the catenary system.
Generally chain or wire rope or special connectors shall be fitted in parts of the anchor leg subject to contact with sea bed or in the vicinity of the attachment point of the mooring line to the offshore unit.
Note that the requirements Part 3, Chapter 13, Section 5, only apply to hawsers used in temporary berthing of shuttle tankers or ship to CALM buoys operated, inspected and maintained in accordance with OCIMF recommendations. Fibre ropes used as hawsers in the long term mooring of Offshore Units to CALM buoy or SALM system shall generally comply with the requirements of this chapter 10 and specific requirements on fibre ropes from this section. They shall be designed for the site specific loading (strength and fatigue) with sufficient redundancy (i.e. considering one line failed case).

*9.1.2* Acceptance of fibre ropes will be based on:
- submission of complete design, manufacturing and installation documentations for design appraisal by LR.
- compliance with API RP 2SM Design, Manufacture, Installation, and Maintenance of Synthetic Fibre Ropes for Offshore Mooring as applicable to the specific rope design, field deployment and service.
- compliance with the requirements of this section and the requirement of LR Rules for Materials (especially Chapter 10) where this is more specific or onerous as applicable to the specific rope design, field deployment and service.
- qualification testing as agreed with LR (and generally in line with API RP 2SM).
- manufacturing and production testing under LR Survey and certification by LR.

### 9.2 Design aspects

*9.2.1* Fibre ropes and associated fittings are to be of an approved design. The following information to be submitted:
(a) Specifications:
- Rope purchaser's functional and manufacturing specifications.
- Rope design specification.
- Rope manufacturing and testing specification.

(b) Plans:
- Rope assembly, spool piece and other fittings (pins, shackles, connectors etc.).

(c) Calculations:
- Strength and fatigue of rope and fittings.

(d) Rope particulars:
- Fibre type.
- Diameter of rope.
- Length at specified reference tension.
- Construction.
- Weight in air and water.
- Sheath~~ing~~ or jacket type and characteristics.
- Terminations.
- Bend limiters.

(e) Rope properties:

- Minimum breaking strength.
- Mean breaking load of rope and coefficient of variation, from tests.

Axial stiffness values (to cover upper and lower bounds of stiffness).

- Fatigue data (tension-tension and compression).
- Creep.
- Hysteresis.
- Torque/twist.
- Resistance to chemical attack in an offshore environment.
- Long-term degradation.
- Inspection, maintenance and repair plan.

*9.2.2* Factors of safety for fibre rope ~~anchor line elements are to be a minimum of 20 per cent higher than the levels given in Section 6 for chain and wire rope materials.~~ are to be a minimum of 20 per cent higher than the levels given in Section 6 for chain and wire rope materials.

$$\text{Factor of Safety} = \frac{\text{Minimum Breaking Strength}}{\text{Maximum tension}}$$

A reduction factor will require to be applied to the standard designated Minimum Breaking Strength, where the test database for the rope type is statistically small.
This does not generally apply to polyester fibre ropes for which sufficient test data, manufacturing and service experience can be documented.

*9.2.3* ~~The~~ ~~f~~Fibre ropes shall remain within the water column under all service conditions and not ~~section of an anchor leg is not to~~ touch the sea bed in any intact or damaged condition.

*9.2.4* Fibre ropes ~~are to~~ shall be kept sufficiently far below the waterline, and below the connection point on the unit, to avoid any possibility of contact damage, degradation by UV exposure, excessive marine growth developing on the sheathing, detrimental intermittent soaking/drying etc.

**9.3 Manufacture**

*9.3.1* Fibre ropes are to be manufactured at a works approved by LR for the manufacturing of fibre ropes specified for the project.
The scope of yard approval is to be agreed with LR:
This will generally entail:

- Review of company technical data sheet for the project specific type of fibre rope (fibres procurement, yarn assembly, rope construction, termination, manufactured length and testing), giving details of construction.
- Surveyor inspection of the site where the ropes are manufactured (review of sample manufacturing and testing procedures, quality controls in place, quality assurance certification in place).
- Witness of manufacturing and break tests on at least two sample ropes of same material, construction and termination and with diameter and reference break strength encompassing that specified for the specific project.

**9.4 Additional specific requirements**

*9.4.1* The purchaser is to specify the project specific material, manufacturing and testing requirements where these complement, exceed or are more onerous than those of this Section 9, Chapter 10 of the Rules for Materials (e.g. chain length and tolerances, maximum yield strength, coating, reference link identification etc.) or API RP 2SM.
These shall be reported and agreed with LR.

*9.4.2* A datasheet is to summarise all characteristics of each fibre rope segment as necessary to ensure satisfactory deployment of the rope within the Positional Mooring System and to support the in service inspection, repair and maintenance plan.

*Existing Section* 10 *has been deleted. Sections* 11 *to* 16 *have been renumbered* 10 *to* 15.

## ■ *Section ~~11~~10*
## Fairleads and cable stoppers

**~~11.1~~ 10.1 General Requirements**

*(Part only shown)*

*~~11~~10.1.3* Fairleads and stoppers and their supporting structures are to be designed for a mooring line pull load equivalent to ~~either~~:

- the mooring line maximum design load ~~when~~ as defined from intact mooring load case (as defined in Sections 4, 5 and 6) for a range of mooring line pull angles as substantiated by analyses (including a 5 degrees contingency) ~~or the rated minimum break strength of the anchor line, but~~

and

- the maximum break strength of the main component (steel wire rope, chain or fibre rope), in "as new" condition, directly acting on or closest in the load path to the structure under consideration. The range of mooring line pull direction shall match that reported in Section 10.1.2. The maximum break load is generally to be based on expected maximum break strength plus two standard deviations (when sufficiently document from manufacturer´s test data), otherwise not less than 110% of the nominal minimum break strength of the mooring line component.
  For this case, special consideration will be given to acceptance of local yielding and deformation of fairleads and stoppers when it can be shown:
  - The support structure to the fairlead or stopper satisfies the requirement of Pt 4, Ch. 6,1.1.6.
  - The deformation does prevent repair or replacement, does not otherwise affect the integrity of the overall hull, does not lead to progressive collapse, has no substantial consequences, such as, loss of life, uncontrolled outflow of hazardous or polluting products, collision, sinking.
  - The fairlead or stopper can be readily inspected and can be repaired or replaced offshore. Specific inspections, repair or replacement procedures are documented in IMR Manual and sparing policy ensures spares are readily and locally available.

The maximum permissible stresses for the design cases given in this sub-Section are to be in accordance with Pt 4, Ch 5,2.1.1(b) for the intact design load case and Pt 4, Ch 5,2.1.1(c) for the maximum break strength case.*See also* 10.1.8 and Pt 4, Ch. 6,1.1.6.

*~~11~~10.1.4* Fairleads, stoppers and support structures shall also be assessed for the mooring line load from damaged mooring load case (as defined in Section 4,5 and 6) for *a* range of mooring line pull angles as substantiated by analyses (including a 5 degrees contingency).The maximum permissible stresses for the design criteria given in this sub-Section are to be in accordance with Pt 4, Ch 5,2.1.1(~~c~~b).

*Existing paragraphs* 11.1.5 to 11.1.8 *have been renumbered* 10.1.5 to 10.1.8.

*10.1.9* For permanent mooring systems it is recommended that those lengths of the mooring lines which lie over a fairlead or other similar curved surface are not maintained for any extended period of time at the operating tension that would normally apply to the main part of the lines, but rather only for temporary line tension adjustments that might be necessary for inspection, maintenance or repair. It is generally preferable to have a suitably designed stopper holding the mooring line load outboard of the fairlead. Where applicable the long term detrimental effect of the wheel type fairlead action on the mooring line should be assessed and documented. Note: API RP 2SK etc.

*10.1.10* Hawse pipes, guide pipes, ~~or~~ bend shoes and fairleads etc. used in the mooring system are to have adequate strength for the imposed loads. Detailed assessment of the interaction between these devices and mooring line chain or cable shall be documented. The design should take into account the inter-link locking mechanism and the loads required to align the device with the cable through swivel or articulation as well as the intermittent contact interaction in the area where the mooring line separates from the support or bearing surfaces. Hawse pipes or guide pipes when located inside tanks are to also be ~~considered~~ designed for sloshing forces). Close fit between mooring line and mooring line bearing arrangement shall be designed to minimise detrimental bending and stress concentrations in both mooring line and the mooring line bearing arrangement. The design shall ensure the bearing arrangement and mooring line bearing on it can be inspected and replaced in service.

*10.1.11* Sensitivity of the design to the actual long term performance of the bearings are to be considered.

*10.1.12* The fairlead, stoppers and bending shoes shall be protected against corrosion and designed such that their performances are not affected by corrosion.

## ■ *Section ~~12~~ 11*
## Anchor winches and windlasses

**~~12.1~~ 11.1** **General**

*~~12~~11.1.1* This Section applies to winches and windlasses designed actively to control anchor line tensions in-service, or to release anchor lines in an emergency.

*~~12~~11.1.2* Special consideration will be given to requirements for winches and windlasses for passive mooring systems, or permanent mooring systems.

*~~12~~11.1.3* Machinery items are to be constructed to recognised design Codes and Standards. The relevant requirements of Part 5 may be used as guidance for small and simple equipment, but ~~for larger and more complex designs~~ special analysis techniques such as finite element methods (or equivalent) are considered to be more appropriate.

*~~12~~11.1.4* Machinery items are to be installed and tested in accordance with the relevant requirements of Part 5. For electrical and control equipment, *see* Section ~~13~~12.

*11.1.5* Along this Section the maximum break load refers to the maximum break strength (as new and based on expected maximum break strength plus two standard deviations) of the main component (steel wire rope, chain or fibre rope) directly acting on or closest in the load path to the structure under consideration and is generally not to be taken lower than 110% of the nominal minimum break strength of the component.

**~~12~~11.2 Materials**

*~~12~~11.2.1* Materials are to comply with the Rules for Materials. Alternatively, materials which comply with national or proprietary specifications may be accepted, provided that these specifications give reasonable equivalence to the requirements of the Rules for Materials, or are approved for a specific application. Generally, survey and certification are to be carried out in accordance with the requirements of the Rules for Materials.

*~~12~~11.2.2* For the selection of material grades, individual components of anchor winches and windlasses are to be categorised as primary or secondary.

*~~12~~11.2.3* Components where the failure would result in the loss of a primary function of the winch or windlass are considered to be 'primary components', *see also ~~12~~11.2.5*.

*~~12~~11.2.4* All other components where the failure would not result in the loss of a primary function of the winch or windlass are to be categorised as 'secondary components'.

*~~12~~11.2.5* Primary components which are designed with an adequate degree of redundancy in their operation will be specially considered and may be categorised as secondary.

*~~12~~11.2.6* Material grades for all components are in general related to the thickness of the material, the structural category and the minimum design air temperature and are to be selected to provide adequate notch toughness.

*~~12~~11.2.7* Material grades for welded plate components are in general to comply with Pt 4, Ch 2,4. For thicker plates and/or lower design temperature the steel grades will be specially considered.

*~~12~~11.2.8* Material grades for components which are not subject to welding will be specially considered.

*~~12~~11.2.9* Castings and forgings are to comply with Chapters 4 and 5 of the Rules for Materials respectively and the requirements for notch toughness in relation to the design air temperature will be specially considered.

*~~12~~11.2.10* Non-ductile materials are not to be used for torque transmitting items or for those elements subject to tensile/bending stresses.

*~~12~~11.2.11* Spheroid graphite iron castings are to comply with Ch 7,3 of the Rules for Materials, Grades 370/17 or 400/12, or to an equivalent National Standard.

*~~12~~11.2.12* The use of grey iron castings will be subject to special consideration. Where approved, they are to comply with the requirements of Ch 7,2 of the Rules for Materials. This material is not to be used for gear components.

*~~12~~11.2.13* Brake lining materials are to be compatible with operating environmental conditions.

**~~12~~11.3 Brakes**

*~~12~~11.3.1* Each anchor winch or windlass is required to have one primary braking system and one secondary braking system. The two systems are to operate independently. The requirements of ~~12~~11.5 are to be complied with.

*~~12~~11.3.2* The braking action of the motor unit may be used for secondary braking purposes where the design is suitable.

*~~12~~11.3.3* A residual braking force of at least 50 per cent of the maximum braking force required by ~~12~~11.5.1 is to be immediately available and automatically applied in the event of a power failure.

**~~12~~11.4 Stoppers**

*~~12~~11.4.1* If the winch motor is to be used as a secondary brake then a stopper is to be provided to take the anchor line load during maintenance of the primary brake.

*~~12~~11.4.2* The stopper may be one of two different types: a pawl stopper fitted at the cable lifter/drum shaft, or a stopper acting directly on the anchor line.

*~~12~~11.4.3* Where the stopper acts directly on the cable, its design is to be such that the cable will not be damaged by the stopper at a load equivalent to the ~~rated~~ nominal minimum breaking strength of the cable (as new).

*~~12~~11.4.4* *See also* ~~13~~12.4.11 and ~~13~~12.4.12, for stopper control station requirements, and ~~13~~12.4.6, for emergency release of stoppers.

**~~12~~11.5 Winch/windlass performance**

*~~12~~11.5.1* The primary brake is required to hold a static load equal to the ~~minimum~~ maximum break strength of the anchor line (at the intended outer working layer of wire rope on storage drum winches). The static load capacity of the primary brake can be reduced to 80 per cent of the nominal minimum break load of the mooring line (as new) ~~that value~~ when a stopper, capable of holding maximum ~~100 per cent of the~~ breaking strength of the line, is fitted.

*~~12~~11.5.2* The secondary brake is required to hold a static load equal to 50 per cent of the nominal minimum breaking strength of the anchor line (as new).

*~~12~~11.5.3* For passive or permanent positional mooring systems the primary brake is required to hold a static load equal to 150 per cent of the winch/windlass capacity, when isolated from operational/survival mooring line loads using a stopper. A secondary brake is not required in this case.

*~~12~~11.5.4* The anchor winch or windlass is to have adequate dynamic braking capability. The two brake systems in joint operation are to be capable of fully controlling without overheating, the anchor lines during:
- all anchor handling operations;
- adjustment of anchor line tensions. (This is particularly relevant where the mooring system has been designed and sized on the basis of active adjustment of anchor lines in extreme conditions, to minimise line tensions.)

*~~12~~11.5.5* *See also ~~13~~12.4* for control of winches, windlasses, stoppers and pawls, for brake fail-safe requirements and standby power for operation of brakes and release of stoppers in the event of a failure of normal power supply.

*~~12~~11.5.6* Means are to be provided to enable the anchor lines to be released from the unit after loss of main power.

*~~12~~11.5.7* On Offshore Mobile Units, ~~T~~the pulling force of the winches or windlasses is to be sufficient to carry out anchor pre-loading on location, to the necessary level. A minimum low-speed pull equal to 40 per cent of the anchor line nominal minimum breaking strength is recommended.

***~~12~~11*.6 Strength**

*~~12~~11.6.1* Design load cases for the winch or windlass assembly and the stopper, when fitted, are given in Table 10.~~12~~11.1. The associated maximum allowable stresses are to be based on the factors of safety given in Table 10.~~12~~11.2.

**Table 10.~~12~~11.1 Design load cases**

| Load Case | Condition | Anchor line load ~~percentage of break strength~~ |
|---|---|---|
| 1 | Winch braked | Maximum break strength ~~100%~~, *see* Note |
| 2 | Stopper engaged | Maximum break strength ~~100%~~ |
| 3 | Winch pulling | 40% of nominal minimum break load (as new) or specified duty pull if greater |
| Notes: Where a stopper is fitted, the anchor line load in Case 1 may be taken as the brake slipping load, but is not to be less than 80% of the nominal minimum break strength of the anchor line (in as new conditions). | | |

**~~12~~ 11.7 Testing**

*~~12~~11.7.1* Tests are to be carried out at the manufacturer's works in the presence of the Surveyor, on at least one of the winches or windlasses out of the total outfit for the unit. The tests to be carried out are given in Table 10.~~12~~11.3. Alternatively, where a prototype winch has been suitably tested, consideration will be given to the acceptance of these results.

**Table 10.~~12~~11.3 Winch/windlass tests**

| Test | Test load |
|---|---|
| Static brake – Primary | Maximum break strength ~~100% anchor line break strength~~ |
| | (or 80% of nominal minimum break strength of mooring line (as new) where stopper is fitted, *see* ~~12~~11.5.1) |
| Static brake – Secondary | 50% anchor line nominal minimum break strength of mooring line (as new) |
| Stopper (where fitted) | Maximum break strength ~~100% anchor line break strength~~ |

| | |
|---|---|
| Motor stall test | Specified stall load |

*~~12~~11.7.2* The residual braking capability is to be verified in accordance with ~~12~~11.5.4.

*~~12~~11.7.3* Each winch or windlass is to be tested on board the vessel in the presence of the Surveyor, to demonstrate that all main aspects including dynamic brakes function satisfactorily.
A static overload test to 125% of the winch´s Nominal Load (defined as the chain or rope tension that the winch is able to maintain continuously when hauling at nominal speed, measured either at the cable-lifter exit, or at the rope exit of the first layer in the case of a wire-drum shall be considered in addition to functional testing carried out on board..
Further guidance on testing to be carried out can be gained from BS 7464:1991/ISO 9089.
The proposed test programme is to be submitted.

*11.7.4* Mooring winches and windlasses are to be regularly tested during service as part of the inspection maintenance and repair plan. Note that winches used in support of inspection, maintenance and repair plan (e.g. to shift chain links in the stopper during inspections) should be maintained as well as winches used in support of mooring line failure or loss of station keeping capability. The failure response procedure is to be kept in good working condition and regularly tested.

**~~12~~11.8 Type approval**

*~~12~~11.8.1* Winches or windlasses may be Type Approved in accordance with LR's *Type Approval Scheme*. Where this Type Approval is obtained, the requirements of ~~12~~11.7.1 may not be applicable.

*Existing Sections 13 to 15 have been renumbered 12 to 14.*

## ■ *Section ~~16~~ 15*
## Trials

**~~16~~ 15.1 General**

*Existing paragraphs* 16.1.1 to 16.1.3 *have been renumbered* 15.1.1 to 15.1.3.

*15.1.4* Disconnect and reconnection of disconnectable positional mooring system are to be tested during the trial campaign.

*15.1.5* The mooring line integrity monitoring system of the positional mooring system is to be tested during the trial campaign.

*15.1.6* For turret moored offshore units, in so far as practical, the rotational resistance of the turret bearing arrangement is to be tested during the trial campaign.

# Part 3, Chapter 14

# Foundations

**Effective date 1 July 2015**

**Existing Chapter 14 has been deleted in its entirety and replaced with below.**

## ■ *Section 1* General anchor requirements

### 1.1 General Anchor Requirements

*1.1.1* This chapter relates specifically to the following anchor types for floating offshore installations at a fixed location: high holding power (HHP) drag embedment anchors, driven and drilled and grouted pile anchors, suction installed pile/caisson anchors and gravity base anchors. Other anchor types will be specially considered. It also relates to the use of catenary and taut mooring line configurations.

*1.1.2* An anchor point is considered to consist of the anchor itself and the chain or mooring line embedded in the seabed.

*1.1.3* The anchor design shall be based upon the expected site and seabed conditions at the proposed anchor point locations. The anchor type, dimensions, weight and other characteristics are to be determined by their ability to develop sufficient vertical, lateral and torsional capacity to resist the design loads with appropriate factors of safety based on a working stress design approach; except where stated.

*1.1.4* The following information is to be submitted:

- Data, calculations and analysis supporting the selection of anchor.
- Anchor details.
- Proposed test loading or line pull in loads at installation.

and in addition for floating offshore installations at a fixed location:

- Soils data for the anchor locations.

*1.1.5* Anchor design using a load and resistance factor design approach will be specially considered. Installation tolerances on anchor pile orientation and verticality shall be defined during the design process and accounted for in capacity calculations and anchor acceptance. Consideration could be given to performing special tests, such as centrifuge model tests, to provide a better understanding of anchor behaviour.

*1.1.6* Consideration is to be given to the anchor installation tolerances on verticality and orientation when designing the connection between the anchor line and the anchor.

*1.1.7* The connection between the anchor line and anchor is to be designed so as to minimise disturbance to the seabed soils during pile installation, as this could reduce the axial and lateral resistance provided by the anchor. Any reduction in anchor capacity is to be taken into account.

### 1.2 Anchor Loads

*1.2.1* Geotechnical design shall take account of the nature of the loading placed upon the anchors as defined by Part 3 Chapter 10.

*1.2.2* It should be noted that the static load case, as defined within these rules, contains an element of dynamic loading.

*1.2.3* The envelope of maximum and minimum axial and lateral loads should be determined based upon the possible range of chain angles, verticality and orientation of the anchor upon installation.

*1.2.4* Except for drag anchors, the effective weight of the anchor should be accounted for in the analyses. In general, this should be added to the anchor loads.

### 1.3 Location control

*1.3.1* Sufficient and professional oversight shall be applied to the setup, configuration, verification and acceptance of a vessel's surface and sub-surface positioning systems where used to compute the real-time absolute positions of anchors and locations on the seabed.

*1.3.2* Full consideration shall be made to ensure that current operations and procedures, together with all previous survey and site data information, references a single and consistent geodetic datum in terms of spheroid, datum and projection.

*1.3.3* Where surface positioning is undertaken using GNSS systems, operations should be undertaken in alignment with IMCA / OGP 015. Alongside tests and checks should be undertaken in port to verify system setup and achievable accuracy at the computational point (e.g. stern roller or crane location.)

*1.3.4* Where sub-surface positioning is undertaken using USBL systems, operations should be undertaken in alignment with IMCA / OGP 017. Verification and offshore calibration operations may be required dependent upon installation tolerance.

**1.4 Allowable Anchor Point Movements and Line Slack**

*1.4.1* Estimated values of anchor point movements in service are to be submitted together with the basis and details of the calculations made. These estimates are to account for the difference between any installation test load or mooring line pull-in load and the loading the anchor may be subjected to in-service.

*1.4.2* The anchor points are to be so designed that their movements remain within tolerable limits. Where applicable other factors such as the effect of reservoir subsidence and post-seismic induced settlement should be considered.

*1.4.3* The potential for the introduction of mooring line slack to the system (from chain cut in during storm loading for example) should be considered. Where applicable, estimates should be made of the amount of slack generated and checks performed to ensure the estimated slack can be accommodated by the mooring system.

*1.4.4* The definition of tolerable limits on anchor point movement is to take into account factors such as allowable line slack, mooring line angle at fairlead, ability to remove line slack in-service, proximity to other subsea infrastructure, effect on other connected infrastructure such as risers. Other factors may also affect the definition of tolerable limits on anchor point movement.

**1.5 General Anchor Structural Requirements**

*1.5.1* Structural strength of the anchors is to be checked for intact, damaged and installation cases in accordance with Pt 4, Ch 5 or a recognised structural design code. Where necessary a detailed finite element stress analysis is to be carried out.

*1.5.2* A fatigue damage assessment shall be performed for both the anchor pile and connection between the anchor line and suction pile taking into account stress ranges due to environmental loading. Particular attention should be given to any stiffening arrangement of the connection between the anchor line and pile.

*1.5.3* For driven anchor piles the effects of driving shall be taken into account in the fatigue damage assessment.

**1.6 General Geotechnical Requirements**

*1.6.1* The geotechnical design of anchors should follow the requirements within these rules and can be performed in accordance with industry recognised methods such as those contained within the latest revision of API RP 2SK, or ISO 19901-7 or a similar internationally recognised standard.

*1.6.2* Analysis of the anchor/soil interaction under design loading is to take account of the non-linear stress/strain behaviour of the foundation soils, stress history and cyclic loading effects on soil resistance.

**1.7 Scour and Erosion**

*1.7.1* The influence of erosion of soils from around and beneath the anchor is to be taken into account in its design. Erosion due to the following causes is to be investigated:

- The effect of waves and currents passing over the seabed at velocities sufficient to dislodge and transport particles of bed materials (scour and sand waves)
- The relief of hydraulic pressures and pore water pressures built up under the foundation due to environmental loading, which may cause the removal of soil from beneath the foundation (sub-surface erosion or piping).
- The effect of interaction between the mooring line and the seabed, for example trenching caused by buried chain around suction anchors.

*1.7.2* As per ISO 19901-4, scour is generally considered to constitute global and local components and seabed level change.
Where appropriate these parameters should be defined. Once these parameters are defined they should be considered within the definition of scour inspection frequency periods, acceptance criteria and trigger points for remedial action.

*1.7.3* The methods proposed, for the prevention of and/or protection against erosion, are to be submitted for approval. Options for scour protection include skirts, rock dump, grout bags and frond mats.

*1.7.4* Any erosion protection system laid on the seabed is to be designed that it will permit free dissipation of pore water pressures that may be generated in the surface soil under cyclic loading conditions.

**1.8 Slope Stability**

*1.8.1* Where the anchor point is located on or near a slope, the influence of the slope on the anchor is to be considered.

*1.8.2* The possibility failure of the slope due to wave or earthquake loading is to be investigated.

*1.8.3* The results of any calculations or tests are to be submitted.

**1.9 Earthquake**

*1.9.1* Where appropriate, the influence of earthquake loading on the anchor point stability is to be fully accounted for in the design in relation to the particular site conditions. This assessment is to consider the site response, potential for seismic liquefaction and any other aspects that may influence anchor points such as slope stability.

*1.9.2* Where appropriate, the possibility of post-seismic induced settlement and its magnitude should be accounted for during anchor design/selection.

*1.9.3* Seismic design and seismic criteria should be considered in accordance with the latest revision of ISO19901-2.

**1.10 Unconventional Soil**

*1.10.1* The site investigation and subsequent design should take into account the presence of unconventional soils, such as those listed in ISO19901-8. It should be recognised that design methods that have been developed and used for design of offshore anchors in conventional soils may not be applicable to unconventional soils and that further investigation and testing may be required. Anchor design for unconventional soils will require special consideration.

## ■ *Section 2*
## Guidelines for site investigation

**2.1 General site investigation requirements**

*2.1.1* The methods of investigation are to be adequate to give reliable information for anchor design and should take account of, but not limited to, the following:
- Nature and stability of the seabed.
- Geomorphology and engineering properties of the strata underlying the seabed.
- Seabed topography in sufficient detail for the type of anchor point being installed.
- Presence of sand waves, ripples & other mobile seabed features.
- Surface deposits, rock outcrops and debris.
- Variations in soil conditions at the anchor point locations.
- Stability of sloping seabeds and other geohazards.
- Natural eruptions and erosion of the seabed due to emissions of gas, mud, fresh water springs etc.
- Presence of shallow gas.
- Other seabed infrastructure.
- Obstructions (manmade or otherwise).

*2.1.2* The extent of investigations is to be sufficient in area, depth and detail to adequately cover the anchor design. The site and complexity of the proposed anchor point arrangements and the anticipated seabed soil conditions to be encountered at the anchor point locations are to be considered in determining the extent.

*2.1.3* Site investigation is to consist of the following phases:
- Desk study.
- Geophysical site investigation.
- Geotechnical site investigation.
- Integration of geophysical and geotechnical data including update of desk study.
- Determination of design parameters.

*2.1.4* Where necessary site investigation phases are to be updated or repeated to ensure sufficient data is available for anchor design.

**2.2 Desk Study**

*2.2.1* The desk study is to be performed prior to commencing other forms of site investigation. In offshore areas where detailed geological data already exist, this information is to be obtained and used to aid determination of the scope and method of site survey.

*2.2.2* The desk study should also consider other anchors or structures that have been installed nearby and take account of information such as installation records or scour inspection reports.

**2.3 Geophysical Site Investigation**

*2.3.1* In absence of a geophysical site investigation standard published by ISO, other good industry practice such as that published by the ISSMGE is to be taken into account when planning and implementing geophysical surveys.

*2.3.2* The geophysical survey is generally to be performed over an area centred on the proposed floating installation location. The number and spacing of survey lines are to be appropriate for the site characteristics and type and number of anchor points.

**2.4 Geotechnical Site Investigation**

*2.4.1* The geotechnical site investigation should be performed in accordance with the requirements of ISO 19901-8. Geotechnical site investigation data is considered to comprise of sample data & associated laboratory testing and in situ test data that has been appropriately interpreted.

*2.4.2* Geotechnical site investigation data is required at each anchor point location and the geotechnical data shall be sufficient to characterise each soil strata found across the site. Where site conditions are geotechnically uniform a reduced amount of geotechnical investigation locations may be justified at an anchor point cluster. Such a reduction in geotechnical site investigation data is to be supported by proper integration of the geophysical and geotechnical data.

*2.4.3* Geotechnical site investigation should extend to a depth greater than the maximum anticipated depth of influence of the anchor.

*2.4.4* More than one geotechnical site investigation location for a gravity base anchor may be required where the soil conditions are variable. For gravity base anchors at least one geotechnical site investigation location should extend to a depth greater than the maximum anticipated lateral dimension of the proposed gravity base. This deeper data may be supplemented by shallower data to provide an understanding of soil variability across the gravity base footprint.

*2.4.5* When planning a site investigation and selecting equipment particular consideration should be given to issues that may affect the likely anchor type(s). For example, particular attention should be given to identifying any thin weak strata which may be critical to sliding capacity of gravity anchors, but of relatively little significance to the design of friction piles.

*2.4.6* The depth accuracy class, defined according to ISO 19901-8, should be selected to be appropriate for the anchor type. Some anchor types, such as a skirted gravity base, may be particularly sensitive to differences in depth of soil strata. In general this should mean a depth accuracy class of Z3, or better (i.e. Z1 or Z2), shall apply.

*2.4.7* The sample class, as described in ISO 19901-8, should be appropriate for the anchor type and design requirements. In general this should mean Class 3 samples, or better (i.e. Class 1 or Class 2), are obtained.

**2.5 In situ testing**

*2.5.1* In situ testing is to be performed in accordance with ISO 19901-8.

*2.5.2* For in situ tests (such as cone penetration tests or field vane tests) the Application Class is to be determined based on the anchor type and site conditions anticipated from the desk study.

**2.6 Interpretation of site investigation**

*2.6.1* The results of the geotechnical investigation are to be interpreted and presented to allow understanding of soil and seabed conditions across the site. If less than one geotechnical investigation location per anchor is supplied then the interpretive report shall include justification for this on the basis of the desk study, geophysical data and geotechnical data.

**2.7 Unconventional soils**

*2.7.1* Site investigation in unconventional soils will require special consideration.

## ■ *Section 3*
## General installation requirements

**3.1 General installation requirements**

*3.1.1* Details of the proposed method of anchor and anchor line installation are to be submitted.

*3.1.2* Except where stated, anchors are not required to be test loaded at installation. However, for catenary mooring systems preloading of the anchor line is to be performed to ensure its alignment through the seabed and to minimise in-service anchor line slack.

*3.1.3* Visual surveys of the seabed are to be performed at the proposed anchor point locations immediately prior to installation. The visual survey should provide confirmation that the anchor point locations and immediate surrounding area are free of any other seabed obstacles or obstructions that may have appeared in the period since the geophysical survey was performed.

*3.1.4* Design installation tolerances shall be included in the installation philosophy and where tolerances are not met further confirmation of anchor suitability should be provided. Anchor approval shall be based upon demonstration that the anchors remain suitable.

## ■ *Section 4*
## Mooring line requirements

### 4.1 Inverse Catenary Analyses

*4.1.1* Analyses should be performed using upper and lower bound soil conditions to determine mooring line inverse catenaries in the soil. These will provide the maximum and minimum expected mooring line angle at the anchor padeye.

*4.1.2* The calculated range of inverse catenaries should be assessed to demonstrate that the worst case anchor loading has been considered.

### 4.2 Mooring Line Preload

*4.2.1* For anchor types not required to be test loaded at installation it is necessary to perform mooring line pull-in at installation to prevent unacceptable mooring line slack due to inverse catenary cut in during storm conditions.

*4.2.2* Details of intended line pull in procedure and load magnitude and any supporting calculations are to be submitted.

## ■ *Section 5*
## Drag embedment anchors – General

### 5.1 General Requirements

*5.1.1* All drag embedment anchors are required to be test loaded at installation to eliminate slack from the grounded section of the mooring lines and to ensure that the mooring line’s inverse catenary is set; limiting unacceptable mooring line slack in-service; to detect damage to mooring components and to provide assurance of the anchors holding capacity. Anchor installation test load procedures are set out in 5.6.

*5.1.2* Appropriate fluke-shank angle should be selected for the soils at the anchor location during the anchor point design phase. It should be ensured that any ballast material included in hollow anchor flukes does not impact on anchors ability to penetrate the seabed.

*5.1.3* It should be noted that limited uplift resistance can be provided by some drag anchors, particularly at shallow seabed penetrations. Mooring systems should be designed to prevent uplift occurring at the anchor or it should be demonstrated that the anchor can provide sufficient vertical load resistance at the intended location.

### 5.2 Drag embedment anchors – Structural aspects

*5.2.1* This sub-Section, and 14.2, apply to drag embedment anchors of high holding power type. Proposals for the use of other anchor types will be specially considered.

*5.2.2* Anchors are to be of an approved type.

*5.2.3* Material selection for drag embedment anchors are, generally, to be in accordance with Pt 4, Ch 2,4, taking the structural category as ‘Primary’.

*5.2.4* Supporting calculations to verify the structural strength of the anchor for design service loads and for proof test loads are to be submitted.

*5.2.5* The anchors are to be manufactured in accordance with the requirements of Chapter 10 of the Rules for Materials.

*5.2.6* Anchors are to be subject to proof test loading in the manner laid down in the Rules. The level of proof test loading for positional mooring anchors is 50 per cent of the minimum rated breaking strength of the attached anchor line.

*5.2.7* Proof load testing of large fabricated anchors (in excess of 15 tonnes mass) may be waived for classification, subject to the following:
(a) Structural strength of anchor type being verified by finite element analysis procedure.
(b) All main structural welds being subject to non- destructive examination as follows at manufacture:
- 100 per cent visual.
- 100 per cent MPI.
- 100 per cent UT/radiographic, for full penetration welds.

*5.2.8* Not with standing the above, attention is drawn to the separate requirement of some National Authorities for proof load testing of anchors.

### 5.3 Drag embedment anchors – Holding capacity

*5.3.1* The requirements of 5.2 are also to be considered, in addition to this sub-Section.

*5.3.2* Factors of safety for anchor holding capacity for floating offshore installations at a fixed location are not to be less than the values given in Table 14.3.1. Anchors for positional mooring of mobile offshore units are to be sufficient in number and holding capacity for the intended service. It is the Owner's/Operator's responsibility to ensure adequate anchor holding capacity for each location or holding ground.

**Table 14.3.1 Factors of safety for anchor holding capacity for floating offshore installations at a fixed location**

| Design case | Anchor load case | Factor of safety |
|---|---|---|
| Intact | Static load, *see* Note 1 | 2,0 |
| Intact | Dynamic load, *see* Note 1 | 1,5 |
| Damaged | Dynamic load | 1,15 |

NOTES
1. Static load refers to steady plus low frequency load components. Dynamic load refers to static plus wave frequency components of loading.
2. Increased factors of safety will require to be applied where the data supporting the anchor selection is not considered adequate in a particular case.
3. Where the use of vertically loaded anchors (VLAs) is proposed, for soft soil areas, special consideration will be given to required factors of safety.

### 5.4 Drag Anchors - Acceptable Design Methods

*5.4.1* For drag anchors, the ultimate holding capacity, penetration and drag are to be based on empirical design data for the specific type of anchor under consideration. The soil conditions at the anchor location and previous experience in similar soil conditions with the specific type of anchor are to be considered.

*5.4.2* Particular consideration is to be given to locations with layered soil conditions and their effect on ultimate holding capacity, penetration and drag.

*5.4.3* The anchor points are to be so designed that their movements remain within tolerable limits. Estimated values of anchor point movements are to be submitted together with the basis and details of the calculations made.

*5.4.4* Anchor sizing charts should be used with caution. Special care should be taken where soil conditions at the intended anchor location differ from those presented in available sizing charts, for example many sizing charts contain no provision for a layered seabed or calcareous soils.

*5.4.5* The use of analytical design methods or numerical analysis to predict drag anchor holding capacity, penetration and drag will be considered as a supplement to 5.4.1, provided that the methods have been calibrated to actual anchor behaviour.

### 5.5 Anchor Trajectory Prediction

*5.5.1* Expected drag anchor trajectory during installation should be submitted to LR for review. This should include expected depth of anchor fluke tip and attitude at the completion of installation activities. This prediction is of particular importance when considering the effects of scour or layered soils.

*5.5.2* Final anchor position after completion of test load should be inspected and recorded/estimated based on expected chain catenary and submitted to LR. Alternatively anchor position may be directly measured using a monitoring device.

### 5.6 Specific Installation Test Load Requirements

*5.6.1* All drag anchors are required to be test loaded at installation to the satisfaction of the LR Surveyor. The methodology for monitoring and accepting load applied and anchor drag during the anchor preload period shall be submitted to LR prior to installation. Records of load and drag versus time shall be submitted to LR once anchor installation is complete.

*5.6.2* Installation test load magnitude is to be agreed with LR prior to installation, and should take account of cyclic loading, potential for scour, unconventional soil types and any other factors which may adversely affect in service anchor movement. Where the above are not deemed to have a significant effect a test load of not less than 80% of the maximum intact load may be appropriate; however in some circumstances a test load of 100% or more of the intact load may be required to demonstrate required anchor performance. The test load is not, however, to exceed 50% of the minimum breaking strength of the mooring line.

*5.6.3* Acceptance of installation test load by attending LR surveyor will be based on assessment of supplied methodology, load achieved, anchor drag and hold period.

*5.6.4* The test load is to be held for a period of not less than 20 minutes. During this time no anchor drag should be observed.
Where it is not possible to monitor anchor position directly during the hold period this should be estimated from vessel position and checked post hold period. Visual ROV inspection of expected anchor position is also recommended.

## ■ *Section 6* Anchor pile

### 6.1 Design Requirements

*6.1.1* Anchor piles are characterised by being relatively long and slender and having a length to diameter ratio or width ratio generally greater than 10.

*6.1.2* Table 14.6.1 defines the design cases and factors of safety to be used for anchor piles for a catenary mooring system. Table 14.6.2 defines the design cases and factors of safety for anchor piles for taut-leg mooring system. For anchor pile clusters the group as a whole is to have a factor of safety as required by Tables 14.6.1 and 14.6.2. Individual piles in a group may have lower factors of safety; for taut-leg anchor piles, the minimum factor of safety for individual piles within a group is to be 1.5.

*6.1.3* Table 14.6.1 and Table 14.6.2 do not apply to axial capacity of piles installed by vibrating hammers.

**Table 14.6.1 Minimum factors of safety for anchor piles for a catenary mooring system**

| Design case | Anchor load case | Factor of safety | |
|---|---|---|---|
| | | Axial loading | Lateral loading |
| Intact | Static load, *see* Note 1 | 2,0 | 2,0 |
| Intact | Dynamic load, *see* Note 2 | 1,5 | 1,5 |
| Damaged | Dynamic load | 1,5 | 1,5 |

NOTES
1. Static load refers to steady plus low frequency, components of loading.
2. Dynamic load refers to static plus wave frequency components of loading.

**Table 14.6.2 Minimum factors of safety for anchor piles for a taut-leg mooring system**

| Design case | Anchor load case | Factor of safety | |
|---|---|---|---|
| | | Axial loading | Lateral loading |
| Intact | Static load, *see* Note 1 | 2,7 | 2,0 |
| Intact | Dynamic load, *see* Note 2 | 2,0 | 1,5 |
| Damaged | Dynamic load | 2,0 | 1,5 |

NOTES
1. Static load refers to steady plus low frequency components of loading.
2. Dynamic load refers to static plus wave frequency components of loading.

*6.1.4* The efficiency of the group, that is its capacity compared to the sum of the capacities of individual anchor piles within the group, is to be checked.

*6.1.5* Consideration is to be given to the possible formation of a post-hole at the pile head and its effect on capacity.

*6.1.6* The influence of pile shoes, internal stiffeners, padeye and any other protrusions should be accounted for within the pile capacity and installation assessments.

*6.1.7* For piles subjected to permanent tension loads, consideration is to be given to long term changes in soil stresses around the anchor piles and upward creep.

**6.2 Axial capacity**

*6.2.1* This sub-Section applies to anchor piles that are either driven or drilled and grouted into the seabed. Piles installed by vibrating hammers are not recommended where axial loading is significant.

*6.2.2* Other methods, than those contained within API RP 2SK, ISO 19901-7 and associated standard, of determining axial capacity are acceptable, provided they are supported by sufficient evidence of their validity together with appropriate laboratory testing.

*6.2.3* For unconventional soils, such as carbonate soils, particular attention should be given to ensure that appropriate design methodology is used. This applies to cohesive and non-cohesive soils.

*6.2.4* The pile design must satisfy the required factors of safety in Tables 14.6.1 and 14.6.2 or pull-out capacity and bearing capacity.

*6.2.5* No end bearing should be taken for drilled and grouted piles unless it can be demonstrated that there is no infill at the bottom of the drilled hole, or the calculations account for the compressibility of such infill.

*6.2.6* A reduction in axial capacity should be considered where large lateral soil displacements are predicted.

*6.2.7* For tension loads, no end bearing (or suction) component at the pile tip is to be considered unless this can be justified based on pile configuration, rate of loading and soil permeability.

*6.2.8* Pile capacity in rock is to be specially considered.

*6.2.9* Consideration should be given to the effect of close spacing of piles, since the ultimate axial capacity of a group can be less than the sum of the individual capacities. This may be determined by consideration of the group as an 'equivalent pier'.

*6.2.10* Appropriate account should be taken of the driving shoe and any other protrusions or add-ons that may affect the internal or external skin friction.

*6.2.11* Drilled and grouted pile design will be specially considered.

**6.3 Lateral Capacity**

*6.3.1* For anchor piles, the lateral capacity and pile response are normally to be determined using a beam-column non-linear soil/structure interaction finite element analysis. The non-linear axial and lateral soil resistance/pile deflection is to be modelled using t-z and p-y curves, respectively.

*6.3.2* It should be demonstrated that the selected p-y curve methods are valid for the soil conditions at the site. For unconventional soil conditions consideration should be given to other p-y curve methods specifically developed for those soil types (*see* guidance note).

**6.4 Installation – Driven Piles**

*6.4.1* Driving stresses and static stresses due to the weight of the hammer are to be considered in the selection of pile driving hammers and pile wall thickness. Driving stresses are also to be included in the assessment of pile fatigue lives. The stresses induced in the pile during driving can be estimated using a wave equation analyses.

*6.4.2* Any effects resulting for the use of a pile guide frame should be considered within the pile design. This may include consideration of disturbance caused during frame installation and removal.

*6.4.3* A full record of the anchor pile driving operation is to be kept; and is to be submitted to LR. The records of the anchor pile driving operation should include the following details:

- Timing of the various operations

- Hammer characteristics (stroke and any measurements of striking energy and energy transmitted to the pile head) and blowcount with penetration
- Configuration of the top of the pile giving the cushion and anvil materials together with primary dimensions
- State of cushion (number of blows suffered and physical appearance) at the start of driving and time(s) at which the cushion is changed.
- Soil plug measurement on completion of driving

**6.5 Installation – Drilled & Grouted Piles**

*6.5.1* The methods for drilling and grouting and details of the plant and materials are to be submitted to LR for approval.

*6.5.2* The construction programme is to avoid leaving holes open for long periods in soils or rock sensitive to exposure to water or drilling fluids.

*6.5.3* A specimen record is to be submitted for approval prior to the installation of the first pile.

*6.5.4* A full record of the drilling and grouting operation is to be submitted to LR and should include the following details:

- Timing of the various operations.
- Method of drilling.
- Density, viscosity, flow rate and pressure of drilling fluid during drilling.
- Description of returns, if any, from the borings.
- Bit pressure, torque and speed of drilling tools.
- Details of circulation loss and any remedies adopted.
- Hole survey details (the profile and linearity of all holes are to be surveyed to their full depth).
- Details of checks made to determine the existence of any material which has fallen into the hole prior to grouting.
- Final position of any reinforcement or insert piles placed.
- Fluid pressure maintained during drilling and grouting.
- Details of the density, flow rates, grout level and pressure of grout during pumping and total volume of grout pumped (means of monitoring should be specified)
- Details of grout mix design and its constituent materials.
- Programme of grout sampling and testing, including measurements of density and grout crushing strength at 1, 2, 7 and 28 days.
- Grout return level check on completion and grout slump level check at least 12hours after completion. These grout level checks should be provided relative to seabed.

## ■ *Section 7*
## Suction installed piles

**7.1 Design Requirements**

*7.1.1* Appropriate failure modes for the soil are to be considered when evaluating the ultimate capacity of suction anchor piles. The installation tolerances are to be considered when assessing failure modes for the soil.

*7.1.2* The suction pile response under axial, lateral and torsional loading is to be determined to ensure that deflections and rotations remain within tolerable limits.

*7.1.3* Consideration should be given to internal soil plug heave.

*7.1.4* Particular consideration should be given to the effect of layered soils on installation.

*7.1.5* The effect of any jetting system or similar installation aids is to be assessed.

**7.2 Acceptable basis for suction installed pile design**

*7.2.1* Suction piles should be designed in accordance with industry recognised practice such as ISO 19901-7.

*7.2.2* Suction piles are characterised by having a large diameter and a length to diameter ratio generally less than eight, and are essentially caisson-type foundations if the length to diameter ratio is less than three.

*7.2.3* Table 14.7.1 defines the design cases and factors of safety to be used for suction anchor piles for a catenary mooring system. Table 14.7.2 defines the design cases and factors of safety to be used for suction anchor piles for a taut-leg mooring system. The axial and lateral factors of safety for suction piles should be accounted for within in the analyses as described within ISO 19901-7 taking account of whether axial loading, lateral loading or combined axial-lateral loading controls the anchor design.

**Table 14.7.1 Minimum factors of safety for suction anchor piles for a catenary mooring system**

| Design case | Anchor load case | Factor of safety | |
|---|---|---|---|
| | | Axial loading | Lateral loading |
| Intact | Static load, *see* Note 1 | 2,0 | 2,0 |
| Intact | Dynamic load, *see* Note 2 | 1,5 | 1,5 |
| Damaged | Dynamic load | 5 | 1,5 |

NOTES
1. Static load refers to steady plus low frequency components of loading.
2. Dynamic load refers to static plus wave frequency components of loading.

**Table 14.7.2 Minimum factors of safety for suction anchor piles for a taut-leg mooring system**

| Design case | Anchor load case | Factor of safety | |
|---|---|---|---|
| | | Axial loading | Lateral loading |
| Intact | Static load, *see* Note 1 | 2,7 | 2,0 |
| Intact | Dynamic load, *see* Note 2 | 2,0 | 1,5 |
| Damaged | Dynamic load | 2,0 | 1,5 |

NOTES
1. Static load refers to steady plus low frequency components of loading.
2. Dynamic load refers to static plus wave frequency components of loading.

*7.2.4* Suction anchor pile analysis is generally performed using either a continuum finite element model or a limit plasticity model of the pile and soil in order to assess appropriate failure modes. Pile response and the determination of soil reaction stresses for structural analysis of the suction anchor pile are to be analysed using non-linear soil/structure interaction finite element analyses.

*7.2.5* The influence of pile shoes, internal stiffeners, padeye and any other protrusions should be accounted for within the pile capacity and installation assessments.

*7.2.6* For suction anchor piles subjected to permanent tension loads, consideration is to be given to long term changes to soil stresses around the suction anchor pile and upward creep.

*7.2.7* Consideration is to be given to cyclic loading effects on pile axial and lateral capacity.

### 7.3 Installation of suction piles

*7.3.1* Soil resistance to suction anchor piles is to be determined. The potential for internal soil heave and soil plug failure during installation is to be considered.

*7.3.2* The record of installation of piles installed by suction is to be submitted to LR and should include:
- Pile penetration
- Pressure differential
- Orientation
- Verticality

## ■ *Section 8* Gravity anchors

### 8.1 General gravity anchor requirements

*8.1.1* Gravity bases should be designed in accordance with industry recognised practice such as ISO 19903 and ISO 19901-4.

*8.1.2* A material factor for soil of 1,25 is to be applied to the design shear strength, tangent of the angle of internal friction of the soil and tangent of the angle of interface friction between the soil and the gravity anchor.

*8.1.3* Appropriate load coefficients will be specially considered for particular applications for catenary and taut-leg mooring systems.

*8.1.4* Appropriate failure modes for the soil are to be considered when evaluating the ultimate capacity of gravity anchors. The installation tolerances are to be taken into account when assessing failure modes for the soil.

*8.1.5* The stability and characteristics of any ballast will require special consideration. In particular the ballast should be capable of withstanding cyclic loading.

*8.1.6* The gravity anchor is to have sufficient strength to account for the stresses due to the applied loading conditions.

*8.1.7* Wave loads on the seabed are to be considered when such loads are unfavourable to stability.

**8.2 Foundation movements**

*8.2.1* Calculations of foundation movements are to include the effects of short-term and long-term loading.

*8.2.2* The following possible causes of vertical movements are to be investigated:
- Immediate settlement
- Secondary settlement due to steady, or permanent, loading
- Long-term consolidation and settlement due to dynamic, static and steady loading.
- Recoverable displacements due to transient loading.

*8.2.3* Particular account is to be taken of the possibility of differential settlement due to variations in soil conditions over the foundation base area.

*8.2.4* The extent of horizontal movements and tilt are to be assessed. The relative magnitudes of recoverable and non-recoverable displacement are to be determined.

**8.3 Foundation Contact Pressure**

*8.3.1* Complete contact with the seabed is to be maintained at all times and the stresses imposed by the foundations on the seabed are to be compressive under all loading conditions.

*8.3.2* Calculations of the local contact stresses between the foundation and the seabed are to take into account the results of the seabed survey.

*8.3.3* Local soil reactions on gravity foundations are to be based on the highest expected values of soil strength in the upper soil layers.

*8.3.4* Unless specifically considered in the design, any voids remaining beneath the foundation after installations are to be filled with cementitious grout (for example).

**8.4 Seabed penetrating elements**

*8.4.1* Where foundations have skirts, dowels or other seabed penetrating elements which transfer load to the seabed, the effect of these components is to be taken into account when determining the efficiency of, and loads in, the foundations for bearing capacity and sliding resistance. These items are to be designed as structural members.

*8.4.2* The resistance of skirts, dowels and other seabed penetrating elements to penetration of the seabed during installation of the foundation and their effect, if any, on water flow beneath the foundation during installation is to be taken into account in the design calculations.

*8.4.3* The penetration resistance of elements such as skirts and dowels is to be based on conservative (upper bound) estimates of soil strength. Also, by considering more typical penetration resistances, account may be taken of the foundation in formulating possible eccentric ballasting requirements.

*8.4.4* The gravity base anchor installation should ensure that any skirts or other seabed penetrating elements penetrate as required by the design.

*8.4.5* Provision is to be made for the relief of water pressure generated within the skirts during installation of the structure.

**8.5 Installation of gravity anchor foundations**

*8.5.1* The positioning of the foundation is to be properly related to the location of the site investigation.

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*8.5.2* Any significant obstructions identified by the seabed survey carried out prior to the installation are to be removed before emplacement.

*8.5.3* Differential ballasting may be required to accommodate non-uniform soil properties or a sloping seabed. In general, reduction of pressure beneath the foundation is not to be used to aid installation, unless it can be demonstrated that washout or flow of soil will not occur.

*8.5.4* Records of settlement and tilt of the structure are to be made during installation and properly correlated to those required to be kept while the structure is in service.

# Part 3, Appendix A

# Codes, Standards and Equipment Categories

## ■ *Section A1* Codes and Standards

### A1.2 Recognised Codes and Standards

*A1.2.21* **Geotechnical**

- Geotechnical & Geophysical Investigations for Offshore and Nearshore Developments, International Society for Soil Mechanics and Geotechnical Engineering, 2005
- ISO 19901-2, *Petroleum and natural gas industries – Specific requirements for offshore structures – Part 2: Seismic design procedures and criteria*
- ISO 19901-4, *Petroleum and natural gas industries – Specific requirements for offshore structures – Part 4: Geotechnical and foundation design considerations*
- ISO 19901-7, *Petroleum and natural gas industries – Specific requirements for offshore structures – Part 7: Station keeping systems for floating offshore structures and mobile offshore units*
- ISO 19901-8, *Petroleum and natural gas industries – Specific requirements for offshore structures – Part 8:Marine Soil Investigations*
- IMCA S 012, *Guidelines on installation and maintenance of GNSS-based positioning systems,* August 2009
- IMCA S 015 *Guidelines for GNSS based positioning systems in the oil and gas industry,* July 2011
- IMCA S 017, *Guidance on vessel USBL systems for use in offshore survey and positioning operations,* April 2011

*Existing paragraph* A1 1.2.21 *has been renumbered* A1.2.22.

# Cross-References

Section numbering in brackets reflects any Section renumbering necessitated by any of the Notices that update the current version of the Rules for Offshore Units.

## Part 3, Chapter 8

5.4.4 Reference to Part 3, App A, A1.2.21 now reads Part 3, App A, A1.2.22

## Part 3, Chapter 10

1.2.5 Reference to Part 3, Chapter 10, 14 now reads Part 3, Chapter 10, 13

1.2.5 Reference to Part 3, Chapter 10, 15 now reads Part 3, Chapter 10, 14

4.2.3 Reference to Part 3, Chapter 10, 14 now reads Part 3, Chapter 10, 13

4.2.3 Reference to Part 3, Chapter 10, 15 now reads Part 3, Chapter 10, 14

Table 10.4.1 Reference to Part 3, Chapter 10, 14 now reads Part 3, Chapter 10, 13

12.1.4 *now* 11.1.4 Reference to Part 3, Chapter 10, 13 now reads Part 3, Chapter 10, 12

12.4.4 *now* 11.3.4 Reference to Part 3, Chapter 10, 13.4.6 now reads Part 3, Chapter 10, 12.4.6

12.4.4 *now* 11.4.4 Reference to Part 3, Chapter 10, 13.4.11 now reads Part 3, Chapter 10, 12.4.11

12.4.4 *now* 11.4.4 Reference to Part 3, Chapter 10, 13.4.12 now reads Part 3, Chapter 10, 12.4.12

12.5.5 *now* 11.5.5 Reference to Part 3, Chapter 10, 13.4 now reads Part 3, Chapter 10, 12.4

12.7.2 *now* 11.7.2 Reference to Part 3, Chapter 10, 12.5.4 now reads Part 3, Chapter 10, 11.5.4

13.1.3 *now* 12.1.3 Reference to Part 3, Chapter 10, 14 now reads Part 3, Chapter 10, 13

14.1.1 *now* 13.1.1 Reference to Part 3, Chapter 10, 15 now reads Part 3, Chapter 10, 14

14.3.1 *now* 13.3.1 Reference to Part 3, Chapter 10, 15 now reads Part 3, Chapter 10, 14

14.3.3 *now* 13.3.3 Reference to Part 3, Chapter 10, 15.1.3 now reads Part 3, Chapter 10, 14.1.3

14.3.3 *now* 13.3.3 Reference to Part 3, Chapter 10, 15.2.8 now reads Part 3, Chapter 10, 14.2.8

14.3.3 *now* 13.3.3 Reference to Part 3, Chapter 10, 15.3.8 now reads Part 3, Chapter 10, 14.3.8

14.3.4 *now* 13.3.4 Reference to Part 3, Chapter 10, 15 now reads Part 3, Chapter 10, 14

14.4.1 *now* 13.4.1 Reference to Part 3, Chapter 10, 13 now reads Part 3, Chapter 10, 12

14.4.1 *now* 13.4.1 Reference to Part 3, Chapter 10, 15 now reads Part 3, Chapter 10, 14

14.4.3 *now* 13.4.3 Reference to Part 3, Chapter 10, 15.3.3 now reads Part 3, Chapter 10, 14.3.3

15.1.1 *now* 14.1.1 Reference to Part 3, Chapter 10, 13 now reads Part 3, Chapter 10, 12

15.1.1 *now* 14.1.1 Reference to Part 3, Chapter 10, 14 now reads Part 3, Chapter 10, 13

15.2.1 *now* 14.2.1 Reference to Part 3, Chapter 10, 13 now reads Part 3, Chapter 10, 12

15.2.1 *now* 14.2.1 Reference to Part 3, Chapter 10, 14 now reads Part 3, Chapter 10, 13

15.3.1 *now* 14.3.1 Reference to Part 3, Chapter 10, 13 now reads Part 3, Chapter 10, 12

15.3.1 *now* 14.3.1 Reference to Part 3, Chapter 10, 14 now reads Part 3, Chapter 10, 13

15.3.4 *now* 14.3.4 Reference to Part 3, Chapter 10, 13.4.8 now reads Part 3, Chapter 10, 12.4.8

## Part 4, Chapter 6

1.1.6 Reference to Part 3, Chapter 10, 10 now reads Part 3, Chapter 10, 6.1.4

1.1.6 Reference to Part 3, Chapter 10, 11 now reads Part 3, Chapter 10, 10

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